Economic and Environmental Considerations for Incremental Cost Analysis in Mitigation Planning

Prepared for
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Water Resources Support Center
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March 1991

IWR Report 91 - R - 1

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp Date Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) IWR Report 91-R-1
6a. NAME OF PERFORMING ORGANIZATION The Greeley-Polhemus Group, Inc. 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION USACE, Water Resources Support Center Institute for Water Resources
6c. ADDRESS (City, State, and ZIP Code) 105 South High Street West Chester, PA 19382	7b. ADDRESS (City, State, and ZIP Code) Casey Building 7701 Telegraph Road Ft. Belvoir, VA 22060-5586
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Headquarters, U.S. Army Corps of Engineers 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DACW 72-86-D-0012
8c. ADDRESS (City, State, and ZIP Code) 20 Massachusetts Avenue, NW Washington, DC 20314-1000	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO.: — PROJECT NO.: — TASK NO: 004 WORK UNIT ACCESSION NO: —

11. TITLE (Include Security Classification)
ECONOMIC AND ENVIRONMENTAL CONSIDERATIONS FOR INCREMENTAL COST ANALYSIS IN MITIGATION PLANNING

12. PERSONAL AUTHOR(S)

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM ____ TO ____	91/3	135

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Environmental mitigation, optimization techniques, ecosystem measurement techniques, economic concepts, critical review of techniques, conceptual models.

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This report is a product of U.S. Army Corps of Engineers "Planning Methodologies" research program managed by the Institute for Water Resources (IWR) which is part of the Water Resources Support Center. The "Incremental Cost Analysis for Mitigation in Planning" is the specific work unit for which this report was prepared. This work unit focusses on investigating the issues, problems and techniques relevant to conducting incremental cost analysis for mitigating fish and wildlife losses resulting from Corps water resources projects. The intent of incremental analysis is to provide information vital to the choice of the overall level of mitigation, as well as to the choice of a particular plan that accomplishes that level. The focus here is on formulating cost effective increments in mitigation, that is on developing the "supply" of mitigation. Although developed to assist mitigation planning, the approaches discussed are equally applicable to environmental restoration and enhancement, or indeed to a wide variety of problems for which the supply or cost of production of environmental outputs is desired. Supply, in combination with empirically or subjectively estimated "value" or demand (not discussed here), can establish the economically appropriate or "justified" quantity of environmental outputs.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL Dave A. Moser, Ph.D.	22b TELEPHONE (Include Area Code) (703) 355-3066 22c OFFICE SYMBOL CEWRC-IWR-R

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

PREFACE

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The specific problem addressed by this report is the necessary requirement for linking mitigation management plans, for which costs can be calculated, to changes in the quantity and quality of fish and wildlife resources. In addition, the general issue of the role of economic analysis in mitigation planning is also explored. The intention is that the report will assist both the economist and the environmental planner in understanding each other in their roles in mitigation planning and how they need to cooperate to improve information and decisions on natural resources.

Many of the issues in mitigation go beyond this narrow focus to the broader area of evaluation and decision making for any natural resource. Environmental modeling has been shown in this report to be extremely important for evaluations and decisions on mitigation. This modelling, however, tends to be concerned with describing and understanding processes of ecosystems that are frequently highly complex. The scientific interest is in answering questions such as: what are the factors that make an ecosystem function as it does?; and, what are the variables that are crucial to its continued functioning? These questions and viewpoints are not the same as those necessary if we are interested in employing economic concepts for environmental resource use and management. The economist is certainly interested in the variables that are important to the functioning of a particular ecosystem. To be of use to economists and economics based decision making, however, these variables must be part of an overall management-biological production model. The concepts of substitution possibilities and incremental response are central to the economics notions of production and choice. Thus, the economist is interested in the overall biophysical response to marginal changes in these variables and in the response of the variables to identifiable management measures. The reasoning is that to deal with environmental restoration and enhancement in a cost-effective manner we need to be able to determine the effectiveness of management measures.

This report was prepared by The Greeley-Polhemus Group, Inc. under terms of a contract with the U.S. Army Corps of Engineers Institute for Water Resources. Dr. David A. Moser of the Research Division, IWR, served as contract manager and Dr. Moser, assisted by Mr. David J. Hill served as final editors. The Chief of the Research Division is Mr. Michael R. Krouse and the Director of IWR is Mr. Kyle Schilling. Mr. Kirby B. Fowler (Economics Branch) and Mr. Phillip Pierce (Environmental Programs Branch) of Planning Division, Headquarters provided valuable insights during the review and editing process.

ECONOMIC AND ENVIRONMENTAL CONSIDERATIONS
FOR INCREMENTAL COST ANALYSIS IN
MITIGATION PLANNING

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EXECUTIVE SUMMARY

Public law and Corps of Engineers (COE) policy require that potential adverse impacts of a project on fish and wildlife resources be estimated during project planning and mitigated during project implementation. Mitigation planning under existing COE policy requires the ability to measure fish and wildlife resources, to estimate the impacts of a proposed project on those resources, and to use an incremental analysis technique to develop a mitigation plan which is cost-effective. Environmental mitigation typically incorporates a narrow range of mitigation plans and thus are not necessarily cost-effective economic strategies. This study was undertaken to accomplish the following:

(1) Describe the underlying problems in achieving cost-effective mitigation plans through incremental analysis;

(2) Identify basic economic concepts relevant to mitigation planning;

(3) Identify and review available fish and wildlife habitat measurement techniques;

(4) Determine which techniques, if any, are applicable to COE project planning for mitigation through incremental analysis;

(5) Evaluate economic models which provide a framework for use of the measurement techniques in incremental analysis for mitigation planning;

(6) Provide conclusions and recommendations for further development of the economic framework.

Three basic economic concepts were investigated for resolving these problems and improving the economic effectiveness of mitigation planning:

- Economic Efficiency (Benefit/Cost Analysis)
- Cost Effectiveness (Current COE Incremental Analysis)
- Other Techniques (Linear and Non-Linear Programming and Other Biophysical Response Models)

The economic efficiency framework is strongly founded in economic theory and provides the basis for much of the analysis of Federal projects. However, for mitigation, this framework requires placing monetary values on environmental resources. A great deal of research has been directed toward improving methods for determining these monetary values, but none of the methods has been accepted for mitigation planning.

Cost-Effectiveness analysis, in general, compares the costs of alternative plans and the least cost plan which meets the objective is selected. Current COE policy requires incremental cost analysis in mitigation planning (EC 1105-2-185). A mitigation plan increment consists of one or more management measures that may interrelate and complement one another, but cannot be functionally dependent. Using this approach does not determine how much mitigation is economically justified nor does not it provide a decision rule for choosing the appropriate level of mitigation. Cost-effectiveness analysis does derive the supply curve for mitigation showing the least cost combination of mitigation measures for various levels of mitigation.

Other techniques includes a variety of optimization and other biophysical and bioeconomic models and methods that have been used or suggested for mitigation planning. Currently all appear to have either conceptual or practical problems. However, a recent development, the Habitat Management Evaluation Model (HMEM), appears to offer significant improvements to incremental cost analysis in mitigation planning.

All of the economic concepts involved in mitigation planning require the measurement of wildlife resources. Numerous wildlife resource measurement techniques were investigated, and four were determined to be potentially applicable and useful to the COE incremental cost analysis for mitigation planning. These are:

- Habitat Evaluation Procedure (HEP)
- Pennsylvania Modified Habitat Evaluation Procedure (PAM HEP)
- Habitat Evaluation System (HES)
- Wetland Evaluation Technique (WET)

HEP is a species based technique that selects a group of representative species and measures the anticipated impacts of the proposed project on those species. HEP is the most widely used and accepted approach by Federal agencies. Its biological models are the most precise and 40% have been validated through field ecological surveys. However, it is the most time and labor consuming, data demanding and costly of the four techniques.

PAM HEP is also a species technique that is based on HEP but uses simplified accounting measures to reduce the complexity of the procedures and to minimize the effort required to obtain habitat measures. PAM HEP draws from the same biologic models developed for HEP and could be used nation-wide. It requires about 70% less time and effort than HEP. Its limited use is due primarily to lack of awareness of its availability. However, some concern has been expressed as to whether its simplified procedures have compromised its validity as a model to predict biologic changes.

For both the species based techniques, the measurement of the quantity of wildlife resources is based on the concept of the Habitat Suitability Index (HSI). HSI's relate attributes of each habitat to the potential biological suitability of that habitat for each species evaluated. The HSI's model the interface between mitigation measures and the target species and embodies the complexity of a biological production function.

HES is a habitat or ecologic community based technique that assesses the ability of the habitat to support wildlife and measures the project-induced impacts on the habitat of the ecologic community.

HES is conceptually the most representative approach to habitat evaluation and is less time consuming and data demanding than HEP. It could have nation-wide applicability. To date it is limited by its available regional biologic models to the Lower Mississippi River Valley.

WET is a habitat or ecologic community based technique that evaluates a series of wetland functions such as nutrient retention, food chain support, etc. on fisheries and wildlife wetland habitats. WET is appropriate for use in screening studies and in rapid evaluation of numerous alternative projects and mitigation plans. WET does not offer a comprehensive approach to fish and wildlife resource evaluation and is not applicable to incremental analysis since it does not provide for quantitative estimates of habitat impacts.

HEP, PAM HEP and HES are compatible with the requirements of the Principles and Guidelines (P&G) to develop project plans including mitigation to achieve maximum net NED benefits, and with recent COE guidance on the use of incremental analysis in mitigation planning.

The latest developments in conceptual models for incremental mitigation planning were identified and reviewed. These fell in two categories: (1) Biophysical Response Modeling; and (2) Habitat Management Evaluation Model (HMEM). The work of Matulich and Hanson (Matulich and Hanson, 1986) in using piece-wise linear functions to represent non-linear biophysical responses as applied to mitigation measures for impacts on wildfowl habitat was shown to be useful for limited applications. However, the approach appears to be too time-consuming and costly for many situations.

On the other hand, HMEM, being developed by the Bureau of Reclamation and the Fish and Wildlife Service, appears to be applicable to incremental cost analysis for mitigation planning in a wide range of projects. HMEM is an interactive, menu-driven computer program that assists users in developing incremental plans to meet mitigation goals. HMEM links the HSI software of HEP to mitigation management actions that affect specific habitat variables and produces the mitigation cost curve required in incremental analysis. At this time, the major effort required to get HMEM ready for wide application to mitigation planning is to develop HSI models that are sophisticated enough to reflect responses to a wide range of possible management activities. In addition, there is a need for developing an informative user's manual and additional testing of software.

The primary conclusions from this study are as follows:

Current methods and procedures for mitigation planning do not provide an adequate basis for determining if a mitigation plan is a cost-effective means of achieving the chosen level of mitigation for a COE project. Mitigation costs, particularly for a large project, could be significantly higher than necessary. What is needed is a method for readily determining the least-cost set of mitigation measures for levels up to 100% mitigation and for displaying these plans effectively to the decision makers for selection of the level of mitigation appropriate for the project under consideration. The method developed should be consistent with basic economic concepts.

At the heart of incremental mitigation planning is the ability to measure the characteristics of each habitat in quantifiable units. HEP, PAM HEP, and HES but not WET are applicable to incremental mitigation planning.

To incorporate the quantified habitat measurements into an economic framework, the use of the Habitat Management Evaluation Model (HMEM) has been determined to offer significant advantages over current approaches to biophysical response modeling or other optimization techniques.

The following next steps are recommended:

A workshop should be convened with representatives from the Corps of Engineers (COE), Fish and Wildlife Service (FWS), Bureau of Reclamation (BuRec) and other agencies involved in developing approaches to mitigation planning to discuss and evaluate the current status of HMEM and the further development required. If HMEM is determined to be as useful as the above evaluation would indicate, then its use throughout the COE districts should be strongly supported.

The HSI models which have not yet been validated by in-depth biological studies of a particular species should be completed as soon as possible.

The HSI models should be reviewed, starting with the validated HSI models, to determine if additional development is needed to match the potentially useful management measures available through HMEM for those species under the most generally applicable conditions.

HEP and HES rely on much the same basic information, such as percent cover of various types, tree type and size, water quality, etc. The question of the validity of the "species approach of HEP versus the "community" approach of HES might be resolved by further comparisons of the two techniques using both techniques applied to the same habitat.

The question of the accuracy and reliability of PAM HEP versus HEP should be resolved by conducting a careful comparison using both techniques applied to the same habitats over various regions of the United States. The use of PAM HEP with HMEM should be tested and, if successful, an integrated user's manual, guidebook and software should be prepared for dissemination to the COE district planners.

However, research into true optimization methods should continue to be supported. These methods include LP, the "piece-wise" LP approximations to non-linear programming (NLP), NLP, and other biophysical and bioeconomic models that can provide benefit-cost curves for incremental mitigation plans.

CHAPTER 1

INTRODUCTION

PURPOSE

This report addresses incremental analysis for environmental mitigation planning for Corps of Engineers (COE) projects which may have adverse impacts on the environment. The purpose of this report is to present a review of concepts and methods useful in understanding the role of economics and incremental analysis in environmental mitigation. It proposes a conceptual framework for integrating habitat measurement techniques with methods for economic optimization so that decisions can be made that optimize resource usage. This is accomplished within current COE policy by reviewing the environmental analysis methods that are available for measuring habitat losses and for assessing the incremental costs of various mitigation strategies. The purpose is to identify a conceptual framework that could integrate the interdisciplinary biological analysis and economic effectiveness needs of mitigation planning.

Requirements for Environmental Mitigation

Federal Requirements: Mitigation is generally defined as measures taken to offset a project's adverse impacts on a natural resource. Mitigation includes avoiding, minimizing, rectifying, reducing or compensating for adverse impacts. Mitigation of adverse impacts can take various forms, including a broad range of measures both on and off-site to make up for lost habitat, such as creation of new habitat elsewhere or improvements to existing habitats.

Mitigation has evolved as a management tool to meet the Federal and state standards set for resource protection. It is not a new concept and first appeared in the Fish and Wildlife Coordination Act (FWCA) of 1934. Currently, the FWCA requires an assessment of adverse environmental impacts associated with Federal water projects, a Federal authorizing permit, and consultation with the Fish and Wildlife Services (FWS) and head of state agency exercising authority over wildlife in question. The FWS is then responsible to make mitigation recommendations. It is important to note, the FWCA does not require mitigation, only that the FWS must be consulted.

Other Federal Regulations that address mitigation include the National Environmental Policy Act (NEPA). The NEPA is a landmark of environmental legislation and applies to all the activities and programs of Federal agencies (Ecological Services Manual, 1980). Furthermore, it mandates all agencies to consider environmental values along with economic or developmental considerations. Regarding environmental assessments and mitigation, NEPA states that all Federal agencies shall:

> "...utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on man's environment, and identify and develop methods and procedures...which will insure that presently unquantified environmental amenities and values may be given

appropriate consideration in decision making along with economic and technical consideration."

Principles and Guidelines: The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (1983), known as Principles and Guidelines or (P&G), establishes the basic framework for project evaluations used by the COE. It provides "four accounts" for the evaluation of proposed Federal projects. These accounts are:

- o National Economic Development (NED)
- o Environmental Quality (EQ)
- o Regional Economic Development (RED)
- o Other Social Effects (OSE)

These four accounts are consistent with NEPA requirements regarding the significant effects of a plan on the human environment and also address impacts on social well-being.

"The EQ account shows the effects on ecological, cultural, and aesthetic attributes of significant natural and cultural resources that cannot be measured in monetary terms," according to P&G. The OSE account shows the impact of a plan on "life, health and safety." The RED account presents the economic effects at the regional level, including income and employment effects.

The NED account is required as a basis for the evaluation and display of alternative plans. It is expressed in monetary terms. The beneficial NED effects are measures of the increase in economic value to the national output of goods and services from a plan. The NED costs are the opportunity costs of resources used to implement a plan.

P&G directs that the appropriate level of environmental mitigation be included in all Federal alternatives in water resources. In addition, P&G directs project analysts to include the costs associated with this level of mitigation in the NED costs. As a result, Federal water resources projects must be evaluated with respect to the environmental mitigation requirements or needs and within accepted economic principles.

This mitigation analysis, according to P&G, should be:

- o "Determined in consultation with Federal and State fish and wildlife agencies in accordance with the Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661-66[c]), or other appropriate authority;

- o Determined in accordance with applicable laws, regulations and Executive Orders;

- o Planned for concurrent implementation with other major project features where practical."

In the context of NED planning requirements, which focus on economic efficiency and comparative analysis techniques for evaluation of specific project elements and comparison among projects, P&G requires, "in the formulation of alternative plans [that] an effort is made

to include only increments that provide net NED benefits after accounting for appropriate mitigation costs." P&G states that planners should, "include appropriate mitigation of adverse environmental effects, as required by law, in all alternative plans. Increments that do not provide net NED benefits may be included, except in the NED plan, if they are cost-effective measures for addressing specific concerns."

Although mitigation has been receiving a good deal of attention among Federal agencies, nowhere is it specified what methods should be used for developing mitigation plans nor what criteria should be used for decisions regarding "how much mitigation is enough." This has fostered confusion among wildlife managers and has resulted in friction between the COE and the FWS over mitigation planning. The purpose of this report is to present conceptual approaches to integrating habitat measurement into an economic decision making framework so that mitigation plans can be developed that will ensure "the most mitigation for the dollar."

COE Guidance Documents: Two guidance circulars are currently in use by COE planners for the preparation of environmental mitigation plans.

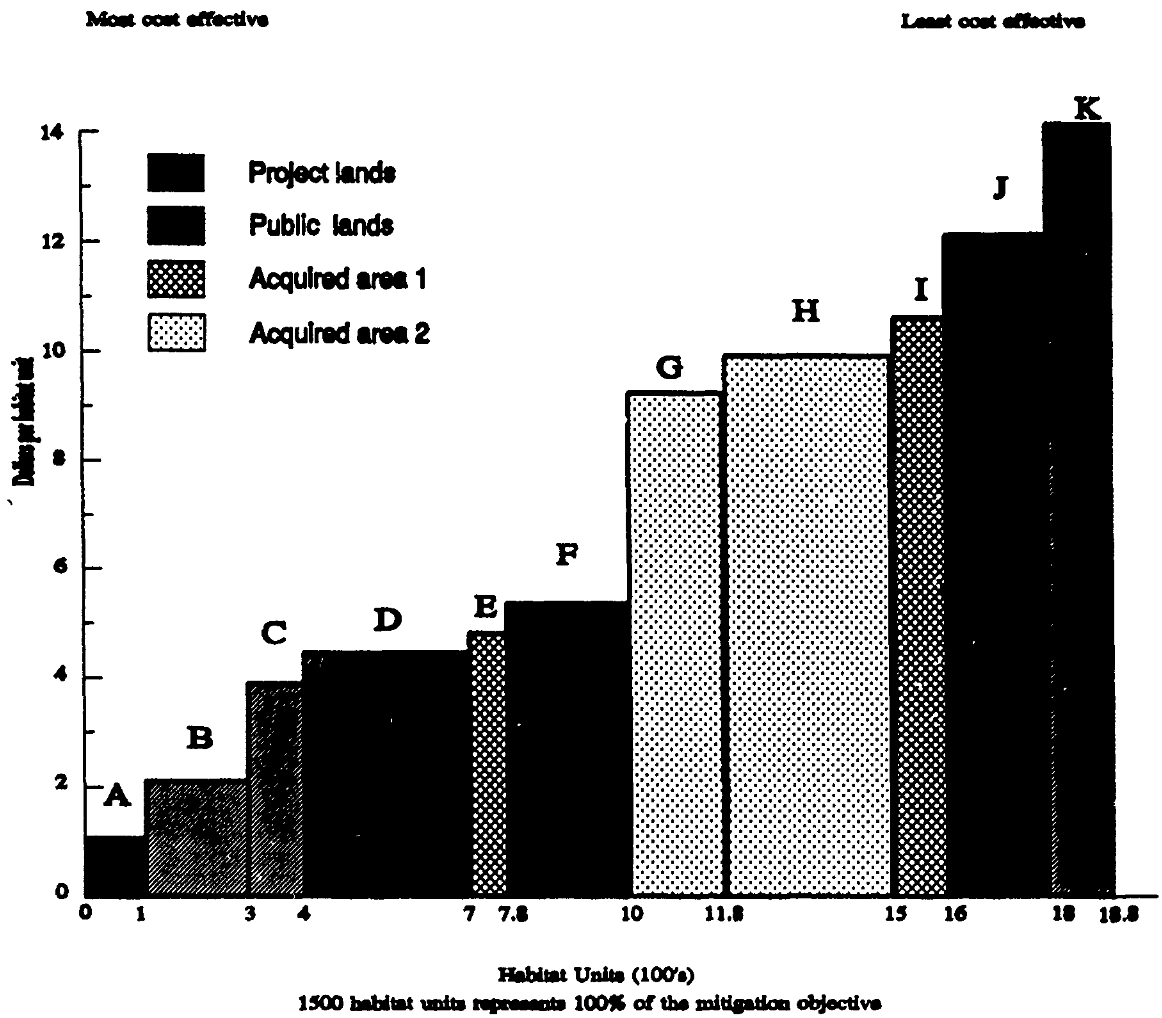
Mitigation of environmental impacts as defined by the COE in ER 1105-2-50, "Fish and Wildlife Mitigation Planning: Incremental (Marginal) Cost Analysis" includes:

- Avoiding impacts by not taking action
- Minimizing impacts by limiting an action or plan
- Rectifying the impacts by repair, rehabilitation or restoration
- Reducing or eliminating the impact over time by preservation and maintenance, and
- Compensating for impacts by replacement or substitution of resources

Additional guidance which complements ER 1105-2-50 is provided in EC 1105-2-185 (Fish and Wildlife Mitigation Planning: Incremental [Marginal] Cost Analysis) 11 March 1988. This circular provides "guidance on performing incremental cost analysis to support recommendations for fish and wildlife mitigation measures involving compensation". The analysis is used to investigate and characterize "how the costs of extra units of output increase as the level of output increases." The result is an "array of implementable mitigation plan increments, ranked from most to least cost effective".

Figure 1-1 presents an example of how the incremental cost analysis results can be displayed to show the relative cost effectiveness of candidate plan increments that address the example mitigation objective: to replace 1500 habitat units (HU's) of wildlife habitat. The increments are identified as A-K, each of which consists of one or more management measures and may involve the use of public or private lands. The least-cost combination of plan increments includes increments A-H which achieve the 1500 habitat units for the 100 percent mitigation objective. These increments are arrayed from the most (increment A) to least (increment H) cost effective expressed as dollars per habitat unit. Increments I, J and K, the least cost effective increments, are also displayed. These increments can be used to replace other plan increments that may be found to be unacceptable or infeasible (for example: if local preferences or constraints may prefer public to private land use and increments I, J or K represents appropriate substitute).

Figure 1-1: Display of Plan Increments from Most to Least Cost Effective



Source: EC1105-2-185, March 11, 1988

In this context, a mitigation plan increment consists of one or more management measures designed to compensate for habitat losses. Management measures may include fencing, landcover manipulation, fish ladders, land acquisition and development, and enforcement of regulations. Therefore, incremental cost analysis represents a planing tool which can be used to develop mitigation alternatives which attain various levels of mitigation objectives. This aids decision makers in determining justifiable levels of mitigation.

FWS Directives: The U.S. Fish and Wildlife Service (FWS), however, has adopted a different perspective from which mitigation decisions have been approached. The FWS mitigation policy (FR 46, WO 15, January 23, 1981) specifies that the level of mitigation should provide full compensation of natural resources or "completely offset losses." The FWS mitigation policy (1981) further specifies that the appropriate level of mitigation depends on the availability or "uniqueness" of the resource based on four separate categories which are show in Table 1-1. For each of the categories, a different mitigation goal is specified which determines the level of mitigation which represents full compensation.

Therefore, the FWS predetermines the mitigation goal and emphasizes that efforts should be directed at determining the least cost means of achieving the appropriate level of mitigation as is required for the particular resource category. Furthermore, the FWCA (P.L. 85-624) requires the FWS to conduct environmental assessments on all Federally funded projects in cooperation with other agencies, including the COE. Since no Federal mandate clearly specifies a particular approach to mitigation planning, conflict exists regarding what approach is best and what full mitigation means.

WHAT IS THE PROBLEM?

The mitigation analysis problem is illustrated in Figure 1-2. This conceptual framework for mitigation planning describes how land use change results from a proposed project. By comparing the with and without project impacts with a habitat measurement model (of which several different approaches are considered in this report), it is possible to quantify the habitat losses. Some losses, such as loss of animals hunted for sport, can translate into measurable monetary gains or losses that will be entered into the NED account. However, other unmonitized habitat losses will require additional study.

In the mitigation planning process the guidelines and directives of the COE and FWS are applied, goals are established for mitigation and possible management measures are considered. The various habitat analysis measurement methods are used to calculate the habitat replacement requirements. Plans are developed (the "Formulate Mitigation Plans" step in the current approach) that utilize various mitigation measures alone or in combination to mitigate the changes that result from the proposed project. Incremental cost analysis is performed, and a decision is made by the COE in consultation with the FWS to mitigate all or some portion of the project impacts.

This is the process that is in place now but there is no assuranace that the amount of mitigation and what combination of mitigation measures chosen are most cost effective. Figure 1-2 indicates that in the "Formulate Mitigation Plans" activity "optimization models" can be used

CATEGORY	CATEGORY DESIGNATION	MITIGATION PLANNING GOAL
1	Habitat is of high value for evaluation species and is unique and irreplacable	No loss of existing habitat
2	Habitat is of high value for evaluation species and is scarce or becoming scarce	No net loss of in-king habitat value
3	Habitat is of high or premium value for evaluation species and is abundant	No net loss of habitat value, while minimizing the loss of in-king habitat value
4	Habitat is of medium to low value for evaluation species	Minimize loss of value

SOURCE: Table 1, Federal Register, January 23, 1981, p. 7646.

Table 1-1: Fish and Wildlife Service Categories for Mitigation

and mitigation cost curves developed. The focus of this project is to describe what methods are available for optimizing mitigation planning that can integrate the environmental analysis capabilities of habitat measurement methods with the incremental cost analysis requirements of COE guidelines.

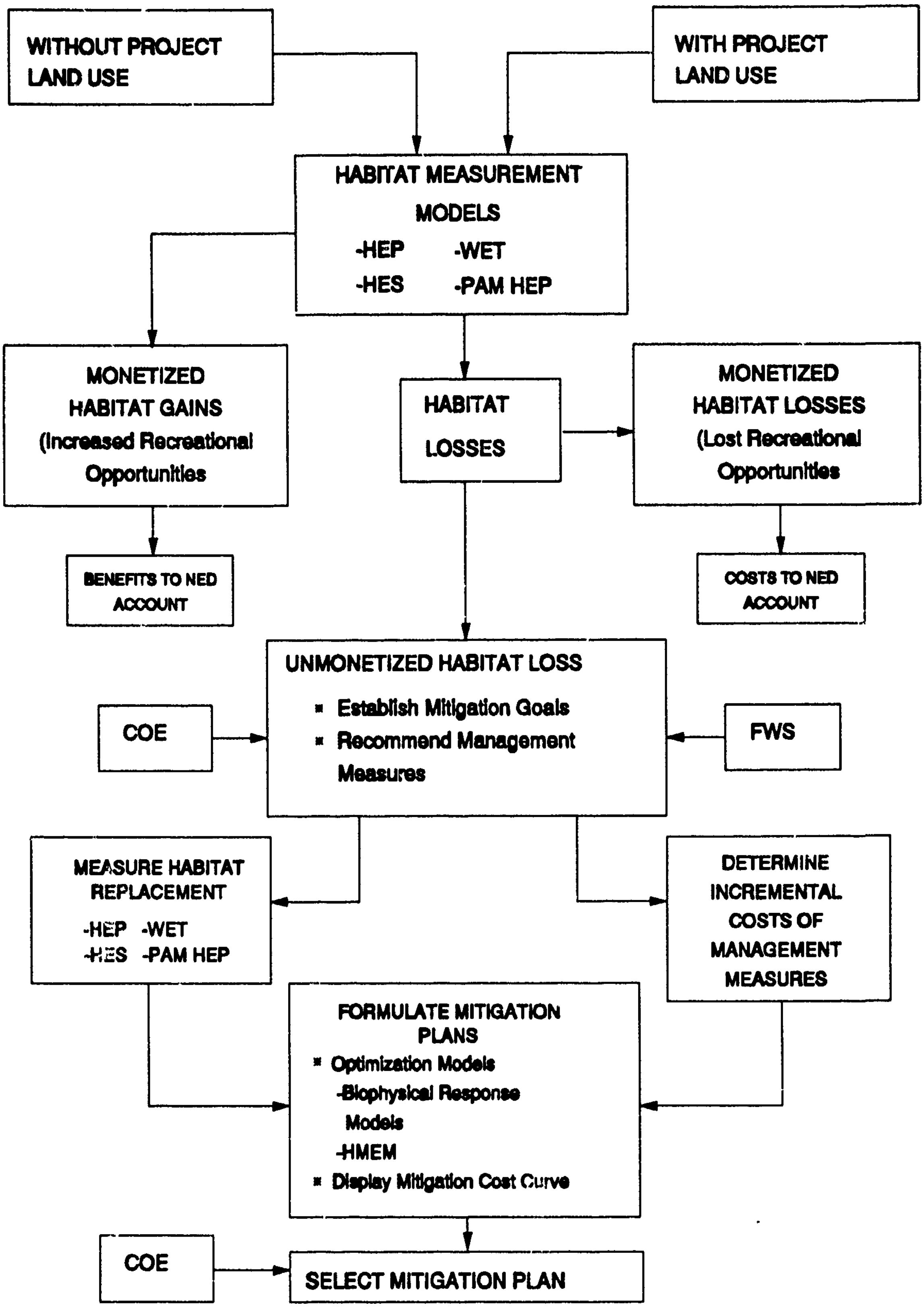
The conceptual framework for mitigation planning can be broken up into two primary stages. First, there is a need to measure habitat losses in some quantifiable manner so that mitigation requirements (goals) can be established. Second, there must be some way to arrange management measures into separable increments and perform incremental cost analysis as a decision making support system to determine the "appropriate and justifiable" level of mitigation and select the most cost-effective plan. The problem is multi-disciplinary in nature and involves the application of economic decision frameworks to environmental management. The disciplinary conflict between economics and biological science lies at the root of the present difficulty in measuring biological or environmental responses to incremental changes in management. The remaining sections of this chapter will examine this problem in more detail.

Valuing Natural Habitat

In order to understand this problem, it is important to understand the difficulty associated with assigning value to fish and wildlife resources. For something to have economic value, it must meet the following two criteria:

1. It must provide some consumers with satisfaction or enjoyment, and
2. It must be scarce in the sense that consumers want more than is available at no cost.

Figure 1-2: Conceptual Framework for Mitigation Planning



Natural habitat certainly meets both of these criteria, however, the difficulty is in determining how to express this value.

One important consideration as emphasized previously is the difference between economic values and monetary or financial values. Economic values consist of market and non-market values. Financial values are defined as actual revenue or sales received by firms or public agencies. Financial values, however, ignore non-market social benefits or costs and, therefore, are only a subset of economic values (Loomis, 1987).

Economic values include commercial, recreational, option, existence, and bequest values, of which only a part can be satisfactorily described in monetary terms and even less is valued in an operating market. The much larger set includes non-market values, such as (1) option value, which refers to an individual's willingness to pay to maintain habitat, such as wildlife recreation opportunities, (2) existence value, which refers to the economic benefit from knowing that natural resources exist, and (3) bequest value, which is the willingness to pay for preserving natural and unique resources for future generations.

The difference between market and non-market values is a source of confusion for some individuals, especially for managers who trade resources in the market place, such as coal and lumber. In addition, others doubt that economic values such as option, existence and bequest can be accurately measured. The government in its role as trustee for the benefit of the public has mandated mitigation to insure that the public trust is not violated because of a current inability to quantify all the benefits and costs of water resource development.

Conflicting Viewpoints

There are two viewpoints from which mitigation decisions have been approached. The first viewpoint is the one adopted by the FWS, where the FWS pre-determines the level of mitigation required (establishes 100% mitigation) and then determines the least cost means of achieving this level. The second viewpoint is the one reflected in the COE guidance on incremental cost analysis, (EC 1105-2-185 11 March 1988) which emphasizes the need to consider a variety of management measures combined in different ways which achieve various levels of fulfillment of the mitigation objectives. Effort is concentrated on developing the least cost means of achieving a variety of levels of mitigation, any one of which may be determined to be appropriate and justified.

Since both the FWS and the COE must jointly develop mitigation plans, conflict arises. The basic problem is that the FWS viewpoint may not be consistent with the evaluation principles that govern the choice of project size or scale. The project scale both affects and is affected by the mitigation plan. The failure to consider multiple mitigation levels associated with different project scales often leads to mitigation plans that are significantly more extensive than warranted by the preposed project and would mistakenly jeopardize beneficial projects. However, since the COE ultimately determines the "appropriate" level of mitigation for its projects, negotiations are common between the COE, FWS and other responsible agencies to determine the definition of 100% mitigation and establish mitigation goals

Current Incremental Mitigation Problems

The concept of mitigation incremental cost analysis is based on the economic concept of marginal analysis. The term "marginal" refers to the additions or subtractions from initial conditions when change occurs. This type of analysis can be used in decision making when the goal is to maximize benefits or minimize costs.

In any decision whether to expand or contract an activity, it is always the marginal cost and marginal benefits that are the relevant factors. Decisions based on average values are likely to lead the decision maker to miss opportunities, some of them crucial.

More generally, to make optimal decisions, marginal analysis should be used in the planning process. This is true whether the decision applies to net benefit maximization, mitigation cost minimization, utility maximization or any other optimization process.

The COE basically follows an economic approach to project planning decisions relying on the net benefit maximization decision rule to "justify" the choice of project and project scale. The marginal analysis performed by the planner trades project benefits and cost until, at the margin, they are equal, thus defining the NED plan. The problem with the current incremental mitigation cost approach is that, since no benefit analysis is performed, there is no beneficial value to trade against cost and no objective decision rule to determine the level of mitigation that is "justified." In theory, however, the mitigation cost analysis should produce a range of mitigation plans that are cost-effective for different levels of mitigation so that the decision maker can make the determination of what is desirable, if not optimal, through subjective judgement. The intention of the incremental cost analysis approach is to at least assure that the choice is from among only cost-effective mitigation plans.

The typical approach being taken by COE district planners is to develop a cost-effective plan for achieving the negotiated 100% mitigation level and then disaggregate the plan into separable increments to perform incremental cost analysis. This is not true marginal analysis. A practical result is that the mitigation plans for levels of mitigation less than 100% will typically not be cost effective. This may be minor for small projects. For large projects with many potential ways of achieving the mitigation objectives, the cost effective 100% mitigation plan may not contain the cost effective 50% or 75% mitigation plan. This may mislead decision makers to selecting plans that do not produce the most mitigation for the dollar. The error is in assuming that disaggregating a plan that is cost effective for one level of mitigation will achieve cost effective plans for other levels. In order to correct this problem, cost minimization for all levels of mitigation must be developed. The mitigation cost curve can then be produced to aid in the determination of the appropriate level of mitigation.

This is not as simple as it may sound and may involve a large number of causal relationships that must be simultaneously analyzed because of the bio-economic nature of the problem. For example, analyzing a mitigation problem consisting of just ten management measures interacting with ten habitats requires the consideration of 100 interactions. This quickly overloads the human mind and the decision maker's ability to make informed decisions.

The remainder of this report will focus on the interaction of habitat measurement within economic frameworks to develop a conceptual model useful for COE mitigation planning. This conceptual model will lay the foundations for developing a decision making approach that will determine optimal mitigation plans applicable to a wide range of typical COE projects.

CHAPTER 2

ECONOMIC CONCEPTS RELEVANT TO THE MITIGATION PROBLEM

INTRODUCTION

> "The Federal objective of water and related land resources project planning is to contribute to national economic development consistent with protecting the Nation's environment, pursuant to national environmental statutes" (Ronald Reagan, February 3, 1983 in the introduction of the P&G).

In principle, classical economic theory applies to the consideration of mitigation measures. For pragmatic reasons this is not always possible. Nonetheless, economic efficiency in the distribution of scarce resources remains the primary economic objective.

The basic elements of economic efficiency are reviewed below as are the notions of constrained cost-minimization, marginal analysis and selected optimization techniques. The purpose of this chapter is to review economic theory relevant to the mitigation problem and to develop some rationale for the deviation from the theoretical ideal.

BASIC CONCEPTS

Economic Efficiency

In the context of the COE program, economic efficiency most nearly means maximizing net benefits. While this is a serviceable intuitive concept economic efficiency is, in fact, more than this.

Society's problem is to decide how scarce factors of production should be allocated among products. This will determine how much of each product is produced and the method by which it is produced. (Products can include flood control, navigation services, hydropower and all water and related land resource project outputs in addition to the more traditional private sector outputs. Factors of production include land, habitat, species, water quantity and quality, etc. in addition to traditional factors like labor and capital. The mitigation alternatives can be viewed as techniques or methods of production). Answering the first question raises a second, how should the products be distributed? Efficiency relates to the answer to the first question; equity to the answer to the second. Efficiency is the primary concern of the analyst dealing with the mitigation problem. Equity is the domain of the decision makers and will not be further addressed.

A society is efficient when it can be said that it is no longer possible to make one person better off without making another person worse off. Such efficient social states are often called Pareto-optimal. To be in any other situation is wasteful. There are three conditions necessary for efficiency.

<u>Efficient Consumption</u>. The pattern of consumption must be efficient. Efficient consumption requires that all individuals place the same relative value on all products, value being assessed at the margin (To the economist this refers to the efficiency locus of all points of tangency between indifference curves in product space). To have an efficient allocation of mitigation (x) and other goods (y) it must be impossible to make someone better off without making someone else worse off.

The value of mitigation is based on the amount of other goods a person is willing to give up for it. This is akin to saying that value of mitigation or other project outputs is based on the willingness to pay concept (It may be useful for the non-economist to keep in mind that though value is often expressed in terms of dollars, dollars are merely a convenient standard of measurement of true value which is based on alternative uses of scarce resources).

Suppose two individuals, one an ecologist and the other a farmer, place different relative values on mitigation (x) and hydropower (y). Say the ecologist will sacrifice 1 kilowatt for 1 extra fish, and vice versa. The farmer, on the other hand, doesn't value fish as highly, and will sacrifice 2 fish for 1 kilowatt, and vice versa. If the farmer provides the ecologist with 2 fish in order to get him to part with 1 kilowatt, then the farmer is as well off as he was before. The ecologist, on the other hand is better off because he only required 1 fish to be as well off and he got 2. Given these starting conditions the terms of trade can be negotiated to the mutual benefit of both parties.

The simplicity of this example does little to illuminate the mitigation problem but it does make two points clear. First, inefficient allocations of resources are possible and wasteful. This was true before the ecologist and the farmer made their exchange. Second, there are gains from trade. When two people willingly enter into trade where goods are valued at the margin, it is possible for both people to be better off or for one to be better off with the other no worse off as a result of trade (For a more thorough treatment of this and the following efficiency concepts any number of economics texts will do. See for example, P.R.G. Layard and A.A. Walters, <u>Microeconomic Theory</u>, McGraw-Hill Book Company, 1978.).

The relevance of all this for mitigation is that given the diversity of human wants and needs in our society there are many efficient allocations of resources among mitigation and other outputs. The efficient allocation sought is that which is pareto-optimal given the preferences of the relevant individuals (publics) (If we look at a different set of individuals, or if individual preferences change, the efficient allocation of goods can also change).

<u>Efficient Production</u>. Efficient consumption ignores the production side of the economy. Efficient consumption identifies an efficient mix of goods (level of mitigation), efficient production identifies the efficient mix of inputs to produce those goods. Production relates to the allocation of factors of production without regard to the pattern of human wants. Efficient production requires that the marginal rate of substitution between all factors be the same in all industries (For economist this means the efficiency locus consisting of all tangencies between isoquants in factor space).

Though it is impossible to do justice to the concept of production efficiency at an intuitive level, the basic premise is that the allocation of scarce inputs (land, water, etc.) should ensure that

one product (e.g., mitigation) cannot be expanded without reducing the other (e.g., hydropower). Likewise, efficient production requires that we exploit differences in the comparative advantage of inputs and allocate inputs to uses where they have a comparative advantage (Intuitively, this means that if an acre of land is more valuable in use as habitat and a pump station location than the next best acre is for use, it should be used in the production of output where it has a comparative advantage. Ignoring for now the entangling notions of value, the concept can be illustrated by saying that if the land is twice as good as the next best acre for mitigation, but ten times as good as the next best pump station location, the land has a comparative advantage in pump stations production and should be used for it).

There is an efficient production allocation of scarce resources for every level of mitigation. But, that allocation changes for every different level of mitigation.

Product-mix Efficiency. Consumption efficiency tells us the amount of other goods a person is willing to sacrifice for more mitigation. Production efficiency tells us the amount of other goods he must (in a production sense) sacrifice for more mitigation. Product-mix efficiency requires that the subjective value of mitigation in terms of other goods should equal its marginal cost (To the economist, this refers to the tangency between the transformation curve and the indifference curve from a social welfare function in product space). As long as society is willing to sacrifice more than it has to, it ought to produce more mitigation, stopping only when what society is willing to sacrifice is exactly equal to what it must sacrifice.

These three elements rather concisely define the necessary and sufficient conditions for economic efficiency. As a theoretical construct they can be intimidating to the uninitiated. The P&G guidelines have been, for the most part, based on these economic principles. Loosely translated for the intuition of non-economists only, in concept the estimation of benefits attempts to reveal consumption efficiency, while the estimation of costs addresses production efficiency. Plan formulation addresses the product-mix efficiency.

Benefit Maximization vs Cost Minimization

Current policy on mitigation requires planners to minimize the cost of producing a prescribed level of mitigation output. COE planners are usually able to vary the levels of both output and costs of projects. The ultimate economic goal is the maximization of net benefits rather than the minimization of costs subject to a given level of output or other constrained optimization problems. The solution of benefit maximization problem can meet the economic efficiency conditions outlined above. It can be shown that solution of this problem implies the solution of the cost minimization problem as well. (A proof is contained in most advanced microeconomic theory texts. See for example, Henderson and Quant's Microeconomic Theory, 3rd ed., McGraw-Hill Book Company, 1980).

Marginal Analysis

The maximization of net benefits is not the objective of mitigation planners. It will be instructive, however, to examine in more detail the conditions for net benefit maximization assuming that benefits from mitigation can be determined. The intention is to illuminate the economic concepts embodied in incremental cost analysis for mitigation.

The technique for determining maximum net benefits is marginal analysis. Marginal net benefits are the addition to total net benefits from one more unit of mitigation. If the marginal net benefits from increasing mitigation by one unit is positive then mitigation should be increased. If marginal net benefits are negative total net benefits can be increased by decreasing mitigation. Thus, a mitigation level can maximize net benefits only if marginal net benefits are zero at that level of mitigation.

Net benefits are maximized when total benefits exceed total costs by the largest amount. Net benefits can be maximized only when marginal benefits, MB, (the addition to total benefits from one more unit of mitigation) equal marginal costs, MC, (the addition to total costs from one more unit of mitigation). If MB = $200,000 and MC = $ 120,000 at a particular level of mitigation, an additional unit of mitigation adds $200,000 to total benefits and only $120,000 to total costs. Net benefits rise by $80,000. Similarly, if MB = $120,000 and MC = $200,000 at a different level of mitigation, an additional unit of mitigation results in net benefits falling by $80,000. As long as MB > MC, net benefits can be increased by adding a unit of mitigation. If MB < MC, net benefits can be increased by decreasing mitigation by one unit. When MB = MC, net benefits cannot be increased by any further change in mitigation.

Using average costs can lead to sub-optimal decisions. While MB may exceed average costs of mitigation, it is possible that MB < MC and though there may be a net benefit, that level of net benefit may not be optimal (If MB are constant at $200,000 and AC = $120,000 for additional mitigation, there may be a tendency for a non-economist to think this is worth doing. However, if the AC are based on initially cheap and subsequently expensive units of mitigation, this may not be a good deal. For example, it is quite possible that the last unit of mitigation in the increment under consideration could cost $500,000. Clearly, if this unit were deleted from consideration, the average cost would fall even further and net benefits would rise).

DIFFICULTIES IN MITIGATION ANALYSIS

The theory is very clear in setting out conditions for efficiency. The NED objective is generally regarded as the economic efficiency criterion. Maximizing net benefits is the means of achieving economic efficiency in project design. As more and more non-economic considerations enter into the analysis of alternative projects the analysis wanders further and further from the theoretical efficiency criteria.

The justification for considering non-economic factors is often based on the normative judgments of analysts and decisions makers who seek their view of equity so that analyses often deviate from the positive notion of efficiency. Nonetheless, economic efficiency remains an essential goal for a society constrained by scarce public and private resources.

If the NED objective, maximizing net benefits, requires economic efficiency then it stands to reason that each separable component of the plan should also maximize net benefits to be efficient. Thus, mitigation, as a separable component of any plan is required by the NED objective to achieve economic efficiency. While some interests might argue that economic efficiency should not be our primary concern, few would argue that achieving economic efficiency would be a vast improvement over the way mitigation has been handled in the past.

Fish and wildlife mitigation, however, does not lend itself well to economic efficiency analyses for a variety of reasons. First, it is very difficult to measure and estimate the effects of proposed plans on the environment. Environmental sciences are still in their infancy and it is very difficult to identify impacts much less quantify them. Thus, we are limited in our ability to identify and measure the "outputs" of mitigation components. Second, when either mitigation outputs or project adverse environmental effects can be identified, they are nearly impossible to value. Most of the environmental effects generated by mitigation or projects are non-market goods, meaning they do not change hands in the market and have no readily observable value. Substantial research has been done to estimate the value of a variety of non-market goods. Unfortunately, many of the estimation techniques are not accessible to COE analysts due to budget, time, and data limitations. In addition, little practical research has been done in the area of environmental mitigation relevant to the COE.

Because the quantity of outputs and their value are frequently unknown it is often a practical impossibility to estimate the benefits from mitigation or the cost of project environmental damage. The net benefit optimization problem clearly cannot be solved if the benefits cannot be estimated. (The difficulties attendant to optimizing the level of mitigation become rather obvious when the functions and arguments of in a benefit relationship are considered. First, the values of mitigation outputs are normally non-market goods that cannot be easily estimated. In addition to the measurement problems, there are conceptual difficulties as well. Recent work in the area of non-market valuation of environmental resources indicate that value may include option, existence and bequest values as well as value in use. Theory and estimation techniques are still developing in these areas. Second, as noted above the quantification of the outputs is currently an extremely ticklish problem. It is even more difficult to link these outputs convincingly to the input factors, X, that planners can control. Even if these difficulties can be overcome estimating the costs, R, of some of the input factors remains a formidable problem). Thus though economic efficiency theory clearly applies to determining the appropriate and justified level of mitigation, it cannot yet be routinely used. As a result, there is no objective way to determine the optimum level of mitigation.

If economic efficiency cannot be achieved for any reason, for example, lack of data, policy decisions, etc. and the desired level of output is specified, it makes economic sense to find the least costly way of producing that level of output. As pointed out above, the least costly combination of resources to produce different levels of output (mitigation) will vary with the level of output. There is no practical way to determine the least costly combination of factor inputs (i.e., specific mitigation plan) for many levels of output (mitigation) from the analysis of only one level. Unfortunately, given a single, 100% mitigation plan, we will normally have no information about what other combination of factor inputs, or in the case of mitigation, what mitigation plan elements, will result in a least cost way of providing any other level of mitigation. For example., it is not possible to derive the least costly mitigation plans for various levels of mitigation (25%, 50%, etc.) from the least costly plan for one mitigation plan (100% mitigation). Having one point on a curve that defines least cost mitigation plan for one level of mitigation does not reveal the any other least cost plans for other levels of mitigation.

If mitigation analysis cannot be done to achieve economic efficiency, the next best alternative would be to achieve specified levels of mitigation in a least cost manner. Looking

at only one level of mitigation almost certainly assures a sub-optimal allocation of resources considering the large number of possibilities that exist.

When the benefits for the different levels of mitigation are unknown, only the costs can be considered quantitatively. In effect the choice becomes one of saying, to provide 50% mitigation costs $x, is it worth it? The answer depends on the judgment of the decision makers. If the answer is yes it makes sense to move to the next level and say, to provide 75% mitigation costs $y, is it worth it? And so the decision process goes until a decision is reached.

This decision process can be aided slightly by moving the decision to a marginal analysis framework. Figure 2-1 shows the total and marginal cost of different levels of mitigation. Marginal costs are defined as the change in total costs in response to an infinitesimally small change in output. (COE analyses do not deal in infinitesimally small changes in plans and discrete incremental changes in plans often results in references to incremental cost analysis.) Incremental cost analysis is in essence marginal analysis where costs change in discrete increments. The marginal cost curve is simply the slope of the total cost curve at corresponding levels of mitigation. (In mathematical terms the marginal cost curve is the first derivative of the total cost curve.) The decision now becomes cast slightly differently. Looking at any level of mitigation we can see the cost of moving to the next larger level of mitigation. The question is no longer, are 16 units of mitigation worth $7,700? The question is now, is the 16th unit of mitigation worth $1,450? Proceeding one acre of land, or one mitigation plan element at a time the individual subjective judgment of the decision maker is forced into a marginal framework and in so doing introduces efficiency into the decision structure.

Thus, under the existing circumstances decision making can be improved by minimizing the cost of producing a variety of mitigation levels. The total costs of these various levels can be reduced to marginal costs and the decision can proceed as described above.

OPTIMIZATION TECHNIQUES

Numerous techniques useful for incremental analysis for mitigation planning are available. Two of them are linear and nonlinear programming. These methods can be successfully used to solve problems like those presented in equations (1) and (2).

Linear and Nonlinear Programming

Linear programming is a technique that maximizes (or minimizes) a linear function of variables subject to a constraint of linear inequalities (Watson, 1968). Its central feature is that it gives actual numerical solutions to problems of making optimum choices when the problems have to be solved within definite bounds or constraints. Linear programming (LP) techniques are particularly useful in situations which involve processes to combine particular inputs to produce a particular output. Typically, LP has been used to address economic costs such as the costs of production when two or more inputs in different proportions are required, or in minimizing shipping costs between several locations.

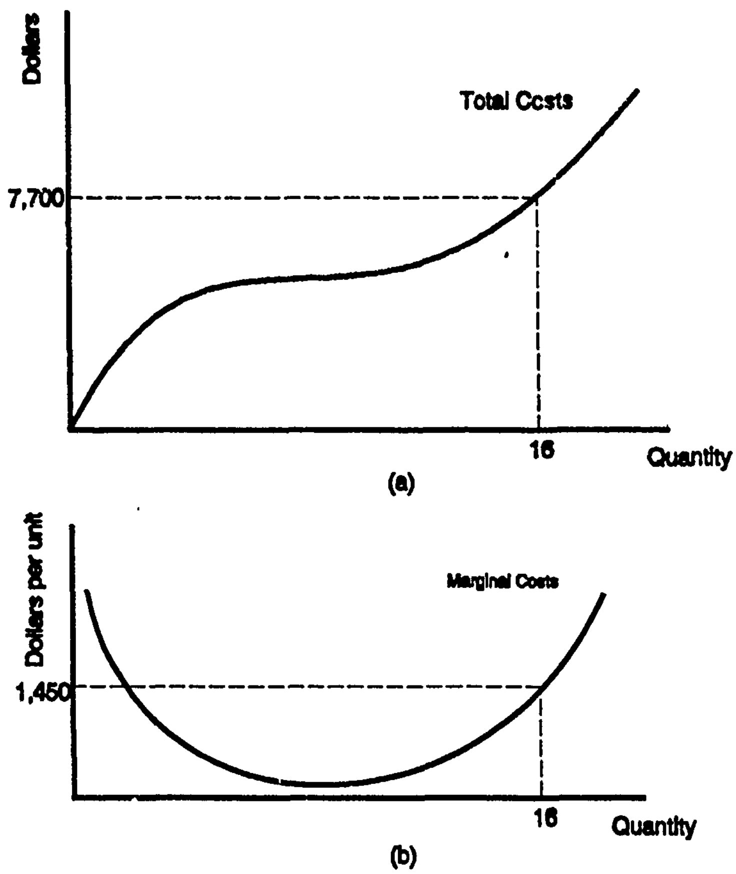


Figure 2-1: Total and Marginal Cost Curves

The problem with applying linear programming to mitigation problems is assumed linearity. Many biological and physical relationships are inherently non-linear. Attempts have been made to reduce this linearity problem by using piece-wise linear functions to represent the non-linear biophysical relationships. Such attempts, however, have encountered computational difficulties (At press time the Institute for Water Resources is sponsoring on-going research to demonstrate the feasibility of using piece-wise linear programming to analyze mitigation plans).

Non-linear programming (NLP) is a way to overcome some of the computational problems associated with piece-wise modeling. NLP conceptually allows the direct use of non-linear response functions to evaluate biophysical relationships. Currently, however, the use of NLP in environmental planning is limited to a few examples of itś actual application.

Dynamic Programming

While analysis of mitigation has no shortage of formidable obstacles to address the fact is the problem is even far more complex than hitherto acknowledged. Many of the effects of mitigation outputs and project adverse environmental impacts change over time. The situation that results from a project or mitigation plan is dynamic, not static. As static analytical techniques are improved research should turn immediately to the problems presented by the dynamic nature of the mitigation problem.

In short, dynamic optimization incorporates the fact that the effects of mitigation output or project adverse effects change over time. The solution to such problems is often to identify a series of actions over time rather than a one time response to the problem (For a discussion of dynamic optimization techniques see for example, Morton Kamien and Nancy Schwartz's Dynamic Optimization: The Calculus of Variations and Optimal Control in Economics and Management, North-Holland, 1981).

CHAPTER 3

ENVIRONMENTAL RESOURCE AND ECOSYSTEM MEASUREMENT TECHNIQUES

MEASUREMENT TECHNIQUES

Currently, a great deal of research is in progress regarding ways to measure habitat. Several models are being designed for specific use in mitigation planning while others are being developed to give biologists a better understanding of the relationships within the habitat. The most prevalent research is discussed below, including some terminology, various ecosystem measurement techniques and evaluation frameworks or approaches including the Habitation Evaluation Procedure (HEP), the Habitat Evaluation System (HES), and the Wetlands Evaluation Technique (WET). In addition the Pennsylvania Modified Habitat Evaluation Procedure (PAM HEP) is presented and discussed as an example of a standardized regional revision to HEP. A bibliography of measurement techniques for mitigation is given in Appendix D.

Habitat Suitability Indices (HSI)

Every species requires a support system from the habitat in which it exists. The quality of this habitat will determine the ability of the species to survive and thrive in the ecosystem. Habitat quality is most often determined by consideration of a variety of characteristics. Population estimates and breeding needs can begin to measure the species' quality. Diversity of species within the habitat is also an important consideration, as is a species' resilience to changes.

Habitat suitability indices, or HSI's, are being developed and validated for use in the Habitat Evaluation Procedure (HEP) for mitigation planning. An HSI is a method of documenting habitat quality for selected evaluation species. Several hundred species will eventually be used as evaluation species, each specified by an HSI index. These species will be "indicators" for the habitat as a whole. Use of selected evaluation species will indicate how the entire habitat will be impacted by natural or man-made conditions.

The HSI is a numerical value that can be compared to other values. It is determined from an evaluation of the ability of key habitat components to supply the life requisites of the species. This becomes an indicator of the habitat's carrying capacity for that species. The HSI, when validated, becomes a standard index for that species. To adjust for habitat quantity varaitions, the HSI is multiplied by the area of available habitat. This new value is a Habitat Unit (HU) and is used in the HEP system for comparative purposes.

Many HSI indices have been developed; the current emphasis is not on developing more HSI's but on validating those previously developed. About 40 HSI's have completed the validation process. Most of this research is being done by biologists at the U.S. Army Corps of Engineers Waterways Experiment Station. The validation process is necessary to ensure reliable measurements of habitat quality.

Relative Value Indices (RVI)

The use of Relative Value Indices (RVI's) provides the capability to take into account the relative value of species through trade-off analysis, which is used in the HEP approach.

Three steps are required to calculate RVI values based on FWS criteria. These steps include: (1) defining the perceived significance of RVI criteria; (2) rating each evaluation species against each criterion; and, (3) transferring the perceived significance of each criterion and each evaluation species rating into an RVI. The criteria utilized in the determination of RVI values include: abundance or scarcity (generally defined at a local or regional level), vulnerability, replaceability, aesthetic value, and management efforts (to preserve or enhance conditions for the evaluation species). With this approach, it is possible to make trade-offs between or among species to reflect their perceived importance.

The consideration of the value of one species relative to another is admittedly subjective, but is a means of introducing some measure of societal priorities into the decision to choose one habitat management plan over another.

Habitat Quality Indices (HQI)

Habitat Quality Indices, or HQI's, are the fundamental measurement values for the Habitat Evaluation System (HES) approach to mitigation planning. The HQI is a function of the general value of a habitat for fish and wildlife populations. The HQI for each land use category or habitat type is derived based on data obtained for several key variables from field measurement programs, literature, and historical information. The value of each variable is converted into an HQI score using a specific functional curve for that key variable and habitat type. In order to make the HQI score represent a specific site, a Habitat Unit Value (HUV) is calculated. The HUV is equal to the HQI multiplied by the Habitat Acreage. This value can then be used in comparative analyses. It should also be noted that the index scores are based on existing conditions. HUV values can be projected to represent future conditions.

The Habitat Evaluation System (HES) was developed by researchers in the Lower Mississippi Valley District of the COE. A more recent enhancement of the HES and development of HSI's is being done by the State of Tennessee, Ecological Services Division of the Department of Conservation. The model was selected to assist in evaluating the bottomland hardwood habitat of Tennessee. It was refined for this work and continues to be expanded in a joint effort with the COE and the FWS. Most recently, the HQI calculations were enhanced to accommodate factors such as tract size and watershed.

Energy Analysis

Another approach to measuring environmental resources is based on energy analysis. The Energy Flow Model (EFM) is based on the assumption that all energy is of equal value to society. This value is calculated in kilocalories, and is assigned to natural resources based on the cost of converting these resources into socially useful forms. The use of kilocalories is a measurement unit that determines the effects on the equilibrium energy levels in the biomass of an area. Impacts can be assessed in terms of changes in energy levels.

Some work is being done to further develop this habitat measurement tool and apply it to mitigation planning. Researchers at the Huntington, W.V. District of the COE are most involved with this approach and have used it on a navigation study in their District.

Threshold Analysis

Threshold analysis is another approach to measuring the relative value of a habitat. This analysis is the first, and fundamental step in the Wetlands Evaluation Technique (WET) being designed and developed in an effort between the Federal Highway Administration and the Waterways Experiment Station of the COE.

The WET model places a value on wetlands based on three major assumptions: opportunity, effectiveness, and significance. Opportunity considers whether a wetland has a chance to fulfill a particular function. Effectiveness considers the probability of a wetland being productive in maximizing the opportunity given it to fulfill that function. Significance considers the degree to which the performed function is valued by society, as partly reflected by its scarcity. The result of the interaction of these is termed "functional significance."

The threshold analysis provides a framework for comparison of projected impacts to the habitat and an analysis of mitigation plans and alternatives. This method is currently being refined and is in use by various state departments of transportation coordinated by the Federal Highway Administration.

User-Day Evaluation Procedure

This approach evaluates the project-induced user-day and monetary losses and gains by a project. User-day figures are the basic measurement for this technique. The development of a user-day figure requires three important population parameters: (1) population density; (2) sustained annual harvest rate; and, (3) hunter success rate. The multiplication of these parameters for each species or group of species in a habitat type, and the summing of all the products yields the user-day value for that habitat type. This user-day value represents the number of user-days available for utilization on one acre of a specific habitat type, assuming that acre is an average acre in the project area. These values can then be used for projections, comparisons, or calculation of a monetary analysis.

This method was developed by the U.S. Fish and Wildlife Service and has been used by the COE. For instance, the Mobile District has used this approach as one of the alternatives to measuring project impacts and developing mitigation plans.

Sustainable Yield

A final approach is based on the theory of sustainable yield. Sustainable yield is based on the need to maintain equilibrium of the species with the demands on the habitat and its ability to supply these demands. In a paper by James Kahn and Michael Kemp (1983), this relationship is summarized as follows, "The point where the locus of biological equilibria, the demand curve, and the supply curve all intersect defines the bioeconomic equilibrium (in an open-access fishery)." As changes in habitat occur, the species may or may not be capable of sustaining its yield to maintain equilibrium.

The Human Use and Economic Evaluation (HUEE) method of mitigation is based on the theory of sustainable yield as a method of measuring biological productivity. It was used by Kahn and Kemp to evaluate the economic losses associated with the degradation of the submerged aquatic vegetation ecosystem in the Chesapeake Bay.

Review of Impact Measurement Techniques

Many methods for measuring impacts to environmental resources are being developed and designed. The most widely used are the Habitat Suitability Indices (HEP method) that are species-based, the Habitat Quality Indices that are community-based (HES method), and the Threshold Analysis (WET method) another community based approach. The HSI's are the most sophisticated and developed models, but also have shortcomings. HSI's are species-derived models specifically for fish and wildlife. In contrast, the WET approach (Threshold Analysis) is developed for eleven different wetland functions, but lacks the high degree of refinement developed for the HSI's. The HQI's used for the HES approach are habitat-derived models that have the potential for application to a broader range of species than the HSI's. However, initial criticism regarding the lack of documentation in developing the HQI's has prevented the model from being used on a broad basis. Work has since been undertaken to address these criticisms and has made the model more reliable and usable. Recent comparisons between results when HEP's HSI models and HES' HQI models were used to measure impacts to identical habitats indicated very little differences in findings.

The remaining methods are more theoretical and still in the developmental stages. Nevertheless, the ideas supporting them are significant for an overall understanding of the considerations of measurement techniques of impacts to habitat.

Based on the measurement needs for mitigation within the cost-effectiveness framework, four techniques have the potential for being used by the COE for mitigation planning. Three of these are HEP, HES, and WET described previously. Since HEP has been most widely used and requires a time-consuming application procedure, many modifications have been made. Of these, one widely used and accepted is the Pennsylvania Modified Habitat Evaluation Procedure (PAM HEP). A second popular modification to HEP is the Wildlife Habitat Assessment Guidelines (WHAG) developed jointly by the Missouri Department of Conservation and the U.S. Soil Conservation Service. PAM HEP will be examined in more detail as a representation of standardized modifications to HEP. Examples of each measurement technique are given in Appendix A.

HABITAT EVALUATION PROCEDURE (HEP)

HEP, a species-based system, was developed by the U.S. Fish and Wildlife Service (FWS) to provide a method for describing baseline habitat conditions and predicting future habitat conditions in terms of habitat quality and quantity. This system is based on the assumption that all habitat has inherent value to wildlife and that impacts on wildlife habitat, in terms of modifications in quality and quantity, can be measured and compared. A HEP study generally consists of three primary steps:

(1) Definition of the study area boundaries and study objectives, and determination of the basic parameters of the field effort required (namely, selection of the species to be considered, determination of the habitats to be sampled, identification of the variables to be measured, and determination of the number and location of the sample plots);

(2) Field assessment of the quality of the habitat for supporting the selected species in the sample plots, the "habitat suitability indices (HSI), followed by computation of the baseline "habitat units" (HU) -the product of the average sample plot HSI's times the acreage of each habitat for each species;

(3) Projection of the HU's under alternate future without and with-project conditions.

Studies involving compensatory mitigation planning include two additional steps:

(4) Definition of compensation goals and objectives;

(5) Computation of acreage and management measures required to attain the compensation goals.

A HEP study is generally performed by an inter-agency team, usually consisting of FWS, COE, and state agency personnel. The team identifies the study area boundaries and study objectives, and selects the representative list of species or species groups for the project area as evaluation elements. The habitat areas, including the types of cover (for life requisites) necessary to support these species (or groups) are also determined.

The selection of species is based on either those species with high public interest or those which provide a broad ecological perspective of the study area. In the latter case, species which are known to be sensitive to specific land use actions, which perform a key role in the ecological community, and/or which represent groups of species are considered for selection.

Habitat suitability for each of the representative species (or "evaluation elements") is rated using the "Habitat Suitability Index" (HSI) for that species (evaluation element) in that habitat type. The HSI is defined as "a numerical index that represents the capacity of a given habitat to support a selected fish or wildlife species". The HSI is determined by the ratio of the study area habitat life requisite values to the optimum habitat values, and is given values from zero for the poorest or absence of proper conditions for the species to 1.0 for the optimum conditions. Thus, HSI may be thought of as an index of carrying capacity.

A Suitability Index (SI) value is determined for each variable for each life requisite evaluation criteria. The SI's are then combined mathematically to derive the HSI for each species evaluated for each cover type. The variables used for each HSI are identified according to three criteria: (1) the variable is related to the capacity of the habitat to support the species; (2) there is at least a basic understanding of the relationship of the variable to habitat; and (3) the variable is practical to measure. Variables must relate to the availability of food, water, cover, reproductive requirements, interspersion (mixtures) of habitats, and special requirements

and considerations. Typical variables for terrestrial species are percent canopy closure, number and types of trees, size of trees, and percent herbaceous vegetation. Typical variables for aquatic species are percent pools, percent cover, substrate for food production, salinity, dissolved oxygen concentration, turbidity and temperature.

The levels of the variables used to determine the SI's are estimated in the field eiher collectively or by each member of the study team individually for each species in each sample plot of each habitat type in the study area. The number of sample plots is determined in accordance with the estimated mean and standard deviation of the variables to achieve the required precision and confidence. The sampling strategy is based either on random sampling or systematic sampling. The SI's obtained by each team member are averaged to obtain the team SI for each sample plot for each species. The sample plot SI's are then used to determine the "computed life requisite value" for each species and cover type. The "actual life requisite" value is then calculated using the relationship:[1]

$$\text{Actual Life Requisite} = \frac{\text{Computed Life Requisite Values}}{\text{Optimum Life Requisite Values}}$$

The HSI for each species is determined as the losest of the actual life requisite values.

The HSI for each species is then multiplied by the total area (acres) of habitat available to that species to determine the total number of Habitat Units (HU's). HU's are the product of quality (HSI) and quantity (area) of the habitat for a particular species and provide a standardized basis for comparing habitat changes over time and space. The estimated HSI's for target years through the project life are used to calculate the HU's for the target years. The HU values are then annualized to obtain an Average Annual Habitat Unit (AAHU) figure for each species. A comparison of AAHU's under future-with project and future-without project conditions yields, for each species, the net change in AAHU's that would result from project implementation. Where tradeoff porrtion of HEP is employed, Relative Value Indices (RVI) for each species must be developed. The RVI's are based on the comparative socio-economic or environmental value judgements. The RVI's are multiplied by the AAHU's for each species with the products summed to obtain the overall HU's in the without- and with-project condition. The difference between the total weighted AAHU's in the without- and with-project condition represent the total AAHU's which must be considered for mitigation.

Mitigation objectives and strategies are determined by the study team. Mitigation increments are identified, such as fencing a wildlife food plot, purchasing acreage for more intensive management of wildlife, restoration of a wetland, and so forth, to restore some or all of the losses. The costs of each increment are estimated, including development, acquisition, and operations and maintenance costs, and expressed as the annual equivalent of the present net worth in dollars per HU. The increments are then rank ordered from least to highest cost, and plotted

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[1]For multi-cover type species adjustments in the computed life requisite values are made based on spatial relationship between all life requisites and the relative abundance of cover types in the study area.

to display the increments in terms of the most cost-effective to the least cost-effective. The recommended mitigation plan is developed by considering the combination of those cost-effective increments which meet the mitigation plan objectives.

Biologically valid HSI models are an essential element of the HEP. That is, the measured variables must relate accurately to the capability of the habitat to support the species being considered. To date, nearly 100 HSI's have been developed. Recently a program has begun to validate the HSI's already developed. Validation involves an in-depth study of a species in its supporting habitat by expert biologists/ecologists. This process should take several years and then it is intended to once again begin developing new models. About 40 HSI models have been validated at this time.

HEP also includes procedures for "trade-off analysis" to take into account the relative value of species in different habitats. The change in average annual habitat units for each species, calculated as indicated above, are multiplied by the relative value index (RVI) for that species to obtain an adjusted value of the habitat units for consideration in the mitigation plan. The RVI's are based on scarcity, vulnerability, replaceability, aesthetics, and management efforts. Application of an RVI to a habitat is much more subjective, and allows the planner to prioritize different species or conditions of the study area. The use of RVI's with HEP is not yet widely used, but is expected to increase as greater confidence is developed with the system.

HEP is applicable to "incremental analysis" since changes in habitat units can be calculated for each mitigation increment, and the costs of implementing that increment give a cost per habitat unit ($/HU) which can be used to justify mitigation measures.

PENNSYLVANIA MODIFIED HABITAT EVALUATION PROCEDURE (PAM HEP)

The Pennsylvania Modified Habitat Evaluation Procedure (PAM HEP), is a simplification of the FWS 1980 HEP. The basic HEP procedures have been carefully modified to reduce the time and personnel resources required for application and analysis while retaining the same basic level of assessment accuracy as the 1980 HEP. PAM HEP was developed by a team composed of the Pennsylvania State Game Commission, the U.S. Fish and Wildlife Service, U.S. Soil Conservation Service, U.S. Army Corps of Engineers, Pennsylvania Department of Environmental Resources, and a consulting firm. Developers of PAM HEP note that HEP was originally designed with the intent that users would modify the approach to best suit their needs. The PAM HEP modifications were made less time-demanding than HEP primarily by streamlining its sampling procedures.

PAM HEP utilizes a series of forms to record all data and calculations. These were designed for computer calculation to further decrease the computational time required in the analysis. Form 1 simply records the study team members and participating personnel. The team determines the study area limits using a modified ecosystem approach to ensure all areas are included which would be significantly impacted by the project. Base maps are prepared using USGS topographic maps, aerial photography (both visual and infra-red) and ground truth as necessary, and the habitats and cover type acreage are measured and listed in Form 2. Form 2 also includes an assessment as to mitigation category (e.g., endangered, threatened, unique, or

of concern), and Form 3 repeats the list of habitats representing critical and unique habitats for the later mitigation planning.

The PAM HEP team identifies a comprehensive list of candidate evaluation species for each basic habitat category (terrestrial, wetland terrestrial and aquatic), selects a minimum of five species known to inhabit the study area, and makes a final selection of at least two species for complete evaluation in each habitat category, Forms 4a, b, and c. The species selection uses a "guild" approach, defined as a group of species utilizing a common habitat resource. Conceivably, PAM HEP would generally use fewer species than HEP. Once the species have been selected, the team identifies a habitat suitability index (HSI) model for use with that species in its specific habitat. In most cases, the HSI's will be the same or similar to those developed by the FWS for HEP analyses.

One of the major savings in time and effort in PAM HEP versus HEP is in the sampling strategy. The PAM HEP team determines "life requisite values" for each habitat/cover type, and a representative number of compartments, generally three to five, are selected for sampling. In this way, sampling conditions of species in an entire compartment significantly reduces the number of sample plots while maintaining adequate coverage of the habitat area. Field sampling then provides the HSI values for the baseline project condition (Forms 5a and b). Mean species HSI are calculated for each land use/cover type by the computer program (Form 6).

PAM HEP uses only three target years instead of four or more under HEP, the baseline (Target Year Baseline or TYB), the Target Year Construction (TYC) when the project is completed, and the Target Year Mitigation (TYM) when all mitigation features have been implemented. HSI values are estimated for TYC (Form 7), and the change in habitat units (HU's) between TYB and TYC for each species in each land/use cover type are computed. The same compartments are used where possible (e.g., some compartments may be removed during construction, and others added during mitigation planning). The change in HU's for each evaluation species is computed (Form 8), and the HU mitigation requirements are listed by land use/cover type and by mitigation category (Form 9). TYC HU's are similarly estimated for project alternatives and summarized (Form 10).

Mitigation plans are developed from an identification of mitigation needs (Form 11) based on evaluation of the field data and the TYB and TYC computations. Mitigation procedures are developed (Form 12) and analyzed as to percent HU's mitigated by land use/cover type for each species (Forms 13 and 14). The final step is to prepare a comparison of HU's by land use/cover type for the target years TYB, TYC and TYM.

In summary, PAM HEP, in spite of its leaner approach, still requires the use of the HEP HSI models which maintains the biological validity associated with the HEP. As noted above, PAM HEP uses a different sampling technique from HEP, and calculates HU's based on selected sample compartment-average HSI's. The PAM HEP model developers feel that since an HU is a relative unit, this procedure is appropriate, as long as it is applied consistently. With HEP, several future target years are considered in this evaluation, whereas with PAM HEP only one is considered. The rationale for evaluating a single set of future conditions rather than several sets is to reduce speculation about the future. It is claimed that through these changes, PAM

HEP saves an estimated 50 to 75 percent of the time it takes to implement HEP while yielding comparable results.

PAM HEP is supported by all of the agencies within Pennsylvania associated with habitat evaluation and mitigation planning. This includes the State Game Commission, Soil and Conservation Services, the State Division of the FWS, and the Philadelphia District, COE. Further development of PAM HEP includes the design of a software package referred to as GDI/HEP. GDI/HEP makes PAM HEP even faster to implement and adds a feature that allows a relatively quick comparison of several mitigation alternatives.

HABITAT EVALUATION SYSTEM (HES)

The Habitat Evaluation System (HES) was developed by biologists of the Environmental Analysis Branch, Lower Mississippi Valley Division (LMVD), COE/Mississippi River Commission. Biologists and researchers from other institutions and agencies assisted LMVD during the development of the HES. The model was developed in response to Federal regulations requiring a community or habitat-based approach for quantifying the impacts to fish and wildlife due to proposed projects. Although the HES procedures can be modified to evaluate habitats for specific species, the HES was designed to evaluate general habitat characteristics that would indicate quality for fish and wildlife populations as a whole. The HES, therefore, does not require detailed data on species populations and life history attributes, but rather determines habitat quality by measuring key habitat variables.

The basic assumption upon which the HES has been designed is that the abundance and diversity of populations in a habitat or community are determined by basic biotic and abiotic factors that can be readily quantified. The HES uses functional curves relating habitat quality to quantitative characteristics of the environment. The method consists of six steps as illustrated in Table 3-1:

The first part of the HES methodology is to delineate acreage of each terrestrial and aquatic habitat type in the project area. As in HEP, the land use and habitat acreage data must be derived for existing conditions, for the future without-project conditions, and for the future with-project conditions for each alternative project plan. Terrestrial habitats include wooded swamps, upland forests, bottomland hardwood forests, open lands, and the terrestrial value of aquatic habitats. Aquatic habitats include streams and lakes or ponds.

Key variables have been identified in HES to relate habitat quality to the carrying capacity and diversity of the habitat in measurable units in terms of a "habitat quality index" (HQI). In many ways, the HQI for a habitat in HES is similar to the HSI for a species in HEP. Functional curves relating variables to HQI have been defined for terrestrial habitat variables such as species association, percent ground cover, percent understory, number of large trees (>16" diameter at breast height (dbh)), and tract size; and for aquatic habitat variables such as fish species association, total dissolved solids, turbidity, chemical type, sinuosity index (for streams) or shoreline development index (for lakes), total fish standing crop. The HQI values range from 0.0 (lowest) to 1.0 (greatest).

1. Obtaining habitat type or land use acreage.
2. Deriving habitat quality index (HQI) scores.
3. Deriving habitat unit values (HUV).
4. Projecting HUV for future without-and with project conditions.
5. Using HUV to assess impacts of project alternatives.
6. Determining mitigation requirements, if any.

Table 3-1: Basic Steps in Conducting a HES Evaluation

The key variables are selected for a particular study area depending on the land uses/habitats present, and the field sampling program is designed to obtain statistically valid results. HQI values for each habitat are obtained, both by a review of the literature and by field sampling. The raw HQI values are multiplied by a weighting factor which has been derived in HES to relate the relative importance of that variable to the overall habitat quality. For instance, the species association in bottomland hardwood forests has a weight of 17 and the percent ground-cover has a weight of 14. The total HQI for the habitat in its existing (baseline) condition is obtained by summing the individual variable weighted HQI scores and dividing by 100.

HQI values for the future with- and without-project conditions over the life of the project (generally 50 years) are then estimated based on both existing data and professional judgement. HQI are also estimated for the future with-project condition for all of the recommended alternative project plans.

Habitat unit values (HUV) are defined as the product of the HQI times the acreage of each habitat. The HUV in HES are similar to the HU in HEP. The HUV are calculated for each habitat and summed to obtain the total HUV for the area in its present condition and for the future in both the without- and with-project conditions, including all alternative plans. The total HUV's over the life of the project are obtained either by adding up the year-by-year values or by integrating under the curve of HUV versus project year in the future. The total HUV divided by the project life yields the annualized HUV for the without- and with-project conditions.

Finally, by subtracting the future with-project HUV values from the present without-project calculation, the losses considered for required mitigation are determined for each project alternative. The HUV's for each habitat can be investigated individually, or the HUV's for all terrestrial and all aquatic habitats (or for all habitats) can be investigated as a group, to determine the mitigation efforts to be considered.

WETLANDS EVALUATION TECHNIQUE (WET)

The Wetlands Evaluation Technique (WET), another community-based approach, was further developed by the Waterways Experiment Stations (WES) of the COE based on the Adamus method originally developed for the Federal Highway Administration, U.S. Department of Transportation. WET was designed to give a broad overview of project impacts on many

functions of wetland habitat. These functions include, in part, groundwater recharge and discharge, floodwater storage, shoreline anchoring, nutrient retention, sediment trapping, food chain support, habitat for waterfowl, fish and wildlife, active recreation, and uniqueness in heritage value. Use of WET can provide planners with insight into the impacts from proposed projects on wetlands, and enables the planner to prioritize areas of mitigation needs. This system could potentially be the starting point for more precise and effective mitigation alternatives.

A project team implements WET by first identifying the physical characteristics of a wetland area through the use of predictors. The predictors are species or characteristics within the habitat which become representative of the study area. Seventy-five predictors of wetland functional value have been defined as shown in Table 3-2. A series of questions are asked for each predictor to more precisely define its relationship to the habitat. For instance, the first question asked is whether the channel flow of the wetlands impact area (WIA) enters through a tidal or nontidal inlet?. The questions for the first 21 functions can generally be answered in the office using map data. The questions for the remaining 54 functions generally require a field survey. The results are entered on Form A which provides the basis for determining the functional opportunity and effectiveness of the wetland impact area.

The social significance of the wetland impact area is determined by answering 77 questions on Form B. For instance, does the WIA drain directly to or overlay a 'sole source aquifer'? The threshold analysis of the probability that the project would alter the hydrologic or biological regime of the wetland is determined by answering 38 questions on Form C. For instance, for a proposed highway project, will the highway be routed downslope of the basin, upslope of the basin, or within the basin?

The predictors are then evaluated for each function based on a series of interpretation keys. The keys provide the instructions for converting the answers to the questions regarding the 75 predictors listed on Form A into a rating of high moderate or low as to the function's effectiveness and opportunity, and the answers to the 78 questions listed on Form B into a similar rating of significance. The ratings of effectiveness and opportunity for each function are combined to give a functional rating, which is combined with the rating for significance to give a final rating of functional significance.

The answers to the 38 questions on the threshold analysis listed on Form C are combined through the use of an impact vector key to determine an overall impact rating. If this rating is low the project is deemed to have negligible impact and no further analysis is required. If the impact rating is moderate or high, the analysis using Form A is repeated for the post-construction condition. This repeat analysis is done in the office using the project plans to determine the answers to the 75 questions. The effectiveness, opportunity and functional ratings are listed on a post-construction Form D using the interpretation keys as before.

The mitigation analysis of WET is initiated by determining the objectives of the proposed project and the project costs without considering mitigation of the impacts on the wetland impact area. The present value of the project costs with full loss of wetland values is entered into Forms M-1 and M-2 as the base plan. The ratings from the original without-project Form D for the functional, significance and functional significance ratings of the without-project condition, and the functional rating of the with-project (post-construction) Form D' are also entered on Form

1. Contiguity
2. Constriction
3. Shape of basin
4. Fetch and exposure
5. Basin surface
6. Wetland surface area
7. Basin area/watershed area ratio
8. Basin area/subwatershed area ratio
9. Location in watershed
10. Stream order
11. Gradient of subwatershed
12. Gradient of tributaries
13. Gradient of basin
14. Perched condition
15. Land cover of subwatershed
16. Land cover trends
17. Soils of subwatershed
18. Lithologic diversity
19. Delta environment
20. Evaporation-precipitation balance
21. Wetland system
22. Vegetation form
23. Substrate type
24. Salinity and conductivity
25. pH
26. Hydroperiod
27. Flooding duration and extent
28. Artificial water level fluctuations
29. Natural water level fluctuations
30. Tidal range
31. Scouring
32. Flow velocity
33. Water depth (maximum)
34. Water depth (minimum)
35. Width
36. Oxygenation of sediments
37. Morphology of wetland
38. Flow blockage
39. Basin alterations
40. Pool-riffle ratio
41. Basin's vegetation density
42. Wetland's vegetation density
43. Sheet vs. Channel flow
44. Wetland-water edge
45. Gradient of edge
46. Shoreline vegetation density
47. Shoreline soils
48. Disturbance
49. Plants: form richness
50. Plants: waterfowl value
51. Plants: anchoring value
52. Plants: productivity
53. Invertebrate density: freshwater
54. Invertebrate density: tidal flat
55. Shore erosion measurements
56. Ground water measurements
57. Suspended solids
58. Alkalinity
59. Eutrophic condition
60. Water quality correlates
61. Water quality anomalies
62. Water temperature anomalies
63. Bottom water temperature
64. Dissolved oxygen
65. Underlying strata
66. Discharge differential
67. TSS differential
68. Nutrient differential
69. Recharge effectiveness
70. Discharge effectiveness
71. Flood storage effectiveness
72. Shoreline anchoring opportunity
73. Shoreline anchoring effectiveness
74. Sediment trapping opportunity
75. Sediment trapping effectiveness

Source: A Method For Wetland Functional Assessment, Volume I (p. 50). DOT FWHA Report IP-83-23.

Table 3-2: Predictors of Wetland Functional Value

M-2. Comparing the ratings for each function for the without-project and with-project conditions provides an indication of the mitigation required.

Only two levels of mitigation are considered in a WET screening procedure, intermediate mitigation (intermediate loss) and maximum mitigation (no loss), besides the base line condition of no mitigation (maximum loss). Maximum mitigation is represented by the without-project condition. Intermediate mitigation is represented by decreasing the rating for each function for the maximum mitigation by one step (ie., from high to moderate or from moderate to low, except a low rating would remain a low rating). The functional effectiveness ratings for the baseline (no mitigation), intermediate and maximum mitigation conditions are listed on Form M-2 and transferred to the appropriate rows on Form M-1.

The base project plan is then modified to yield one or more modified plans to meet either the maximum or the intermediate mitigation objectives. Form A's are filled out for each modified plan to ensure that the functional ratings correspond to the mitigation objectives. The present value of the costs for each of these modified plans is listed on Form M-1. Subtracting the cost of the baseline plan from the cost of the modified plans yields the costs of mitigation. The difference between the mitigation cost for full mitigation and the cost for intermediate mitigation, and the difference between the mitigation cost for intermediate mitigation and the baseline plan yield the incremental costs of mitigation.

The modified plans are evaluated subjectively to select a recommended plan which would provide the maximum degree of protection of the wetlands at least cost.

Built into the system is a recognition that all wetlands function differently. Consideration of social significance, physical and chemical attributes, opportunity, and effectiveness can be applied to the model through the interpretation keys. This procedure helps to define the uniqueness of the area. This also requires that priorities be set for each wetland function. Because many of the functions are incompatible, decisions must be made to determine which are most unique to that wetland and should be considered in mitigation planning.

WET can also be a useful tool for the design of a wetland to compensate for the loss of a wetland area to a project. By working through the model in reverse, planners can evaluate what is needed to create a successful wetland habitat. This can be useful in developing habitat management and mitigation plans.

Many agree that WET provides planners with a good preliminary view of habitat impacts and mitigation requirements for wetlands applications. However, its models have not yet been designed to the extent needed to build overall confidence in the procedure. Proponents of WET are quick to acknowledge that the HEP HSI models are more precise in the area of fish and wildlife than the WET procedure.

CHAPTER 4

CRITICAL REVIEW OF MEASUREMENT TECHNIQUES

REVIEW CRITERIA

Compatibility with Accepted Economic-Ecologic Evaluation Principles as Expressed in P&G and Other Literature

Economic-ecologic evaluation principles are taken broadly to include the goal of achieving economic optimization. Optimization can be achieved through traditional economic efficiency methods, such as benefit/cost analysis, cost-effective analysis, and other methods including linear programming, regression analysis, and input-output analysis. Each of the four habitat measurement techniques was evaluated with regard to its ability to be used with these methods.

P&G provides specific procedures for evaluating national economic development (NED) benefits and costs, (with respect to developing project alternatives prior to developing the mitigation plan), as well as environmental quality (EQ), regional economic development (RED) and other social effects (OSE) for various types of water resources projects. Benefit evaluation procedures rely primarily on the willingness to pay (WTP) principle. When WTP cannot be estimated or is inappropriate, estimates of the costs of the most likely alternative, estimated increases in output of goods and services, or decreases in the cost of production are used. Cost evaluation procedures rely on market prices for private goods and services and for surrogate price estimates or administratively-established values for public goods and services.

The P&G, as quoted in Chapter 2, requires that the plan that maximizes net benefits to NED must be included in the set of alternative plans to be evaluated and is to be selected unless specific reasons are given for an alternate choice. The NED plan should include only increments that provide net NED benefits after accounting for mitigation costs, but alternate plans may include increments with net NED costs if the increments are cost-effective for specific concerns (P&G Section VI paragraph 1.6.2.(b)). The NED and all alternate plans should meet four criteria: completeness, effectiveness, efficiency and acceptability. Effectiveness is defined as the extent to which the plan alleviates the specified problems and achieves the specified opportunities. Efficiency is defined as the most cost-effective means of alleviating the specified problems and realizing the specified opportunities.

P&G directs that the appropriate level of mitigation be included in all Federal alternatives in water resources. In addition, the costs associated with this level of mitigation should be included as NED costs. Recently, specific policy was developed to guide mitigation planning of fish and wildlife resources in COE projects. Circular EC-1105-2-185 states that incremental cost analysis is an investigation and characterization of how the costs of extra units of output increase as the level of output increases. In mitigation planning, such analyses will result in an array of implementable mitigation plan increments ranked from most to least cost effective. This method, however, does not specify the level of mitigation to be achieved. Therefore, the planner, study team, or decision-maker usually attempts to provide 100% mitigation, which is not

necessarily an economically efficient or optimum solution, or simply uses subjective judgement to determine the level of mitigation."

The P&G and current COE policy guidance thus clearly indicate that in cases where specific concerns or objectives can be identified, cost-effectiveness analysis is an accepted economic technique, and the selection of the least cost alternative to meet that concern or objective is an accepted economic evaluation principle. However, a cost-effective plan is not necessarily economically efficient. Therefore, development of methods for introducing benefit-cost or other economic efficiency considerations into mitigation planning are being sought. The ability of HEP, PAM HEP, HES and WET to be used in economic efficiency optimization methods is also a consideration.

Accepted ecologic evaluation techniques stem basically from the environmental impact assessment required under NEPA. The P&G provides specific procedures for evaluating the effects of alternative water resource plans on environmental quality (EQ). The EQ process includes defining the resources, inventorying the resources, assessing the effects of the plan, and appraising the effects. The EQ procedures involve identifying one or more indicators of three attributes - ecological, cultural and aesthetic - and through the use of guidelines utilizing appropriate techniques, appraising each alternative plan as to its significant beneficial and adverse effects on each attribute.

Specific assessment techniques to evaluate mitigation plans from an ecological standpoint are not provided in the P&G, although HEP and HES are mentioned as example techniques. However, Section 201(a) of the Federal Land Policy and Management Act (43 U.S.C. 1701 et seq.) requires, an inventory of all public lands and their resource and other values...giving priority to areas of critical environmental concern. Section 103 of this act defines areas of critical concern to include important fish and wildlife resources. These requirements imply that the use of habitat-based procedures are acceptable for fish and wildlife ecological evaluations. The use of certain species as indicators of habitat conditions are acceptable under the P&G EQ procedures. The use of standing crop estimates or species diversity analyses are also based on accepted ecological principles. Whatever the procedure utilized, it should provide an analytic, scientifically valid appraisal of the beneficial and adverse effects of the without- and with-plan conditions on significant fish and wildlife ecological resources to permit a reasoned choice among alternative plans.

Therefore, the primary criterion for reviewing the four mitigation evaluation techniques is their compatibility with incremental analysis through benefit-cost and/or cost-effectiveness analysis methods as applied to habitat-based ecological evaluation. Secondary criteria are the compatibility of the techniques with other accepted economic-ecologic evaluation principles as noted above, including input-output, linear programming, and multiple regression analysis.

Professional Acceptance

The level of professional acceptance of each technique was ascertained through interviews with persons known to be active in environmental planning, with emphasis on those in the field of habitat evaluation and mitigation planning. (A summary of the views of these professionals is given below in Table 4-1 and the individuals contacted are listed in Appendix B.) Almost all

of these individuals are biologists, and most of them are associated with public agencies, including the COE, FWS and state agencies; some are researchers in the process of developing models, and others are users of the methods who are responsible for implementing habitat and species-based evaluation of fish and wildlife. It was intended to contact professionals with knowledge and experience with all four mitigation evaluation techniques to obtain an individual professional comparison among the methods. However, few such broadly knowledgeable persons were found, so the interviews were generally restricted to determining the acceptability of just one or perhaps two techniques known to the interviewee.

The interviewee was asked specifically to respond to the question, "In your view what is the professional acceptance of those techniques with which you are familiar or at least have some knowledge or experience?" The responses were aggregated and summarized to reflect an overall judgmental average. In this way the usefulness and practicality of each mitigation evaluation technique were determined, based on how well accepted they are by the professionals who are familiar with them on a conceptual and implementable level. Ignorance of, or less familiarity with, the techniques other than the one(s) used by the interviewee could have been a factor influencing their professional opinion. This possibility was explicitly addressed during the interviews in this review.

Cost of Application

The cost of application of these techniques is dependent on many factors, including the geographic size of the study area, the number of species selected for evaluation (for those methods utilizing this approach), the number of models to be developed, and the number of individuals comprising a team. Estimates were obtained for an average cost per acre for the fish and wildlife resources measurement techniques for specific applications of the techniques, even though the average costs may vary widely even for the same technique. These variations were discussed with the professionals contacted and with the developers of the techniques. Other methods of assessing cost were reviewed, such as average man-years for application, and a discussion of the most costly components of the techniques was prepared.

Time Required for Application

Similar to the cost of application, the time required for application is dependent on several factors. The geographic size of the study area, the number of representative species selected (when applicable), and the need to collect data throughout all seasons are some of the major factors in determining time requirements. Consideration of such a wide variety of conditions makes it difficult to provide definitive measurements of time requirements for

TABLE 4-1

SUMMARY TABLE OF PROFESSIONAL'S REVIEW AND COMMENTS ON HABITAT EVALUATION METHODS

CRITERIA	GENERAL COMMENTS.	HEP	PAM HEP	HES	WET
1. Compatibility with accepted economic-ecologic principles.	All techniques similarly compatible except for WET. Economic principles and ecologic principles can not be meshed. Not familiar enough with economic principles to comment.	Species-based habitat evaluation technique. Compatible with incremental analysis and cost-effectiveness techniques.	Species-based habitat evaluation technique. Applicable to incremental analysis and cost-effectiveness.	Community-based habitat evaluation technique. Compatible with incremental analysis and cost-effectiveness.	Community-based habitat evaluation technique. Not designed for economic evaluation. Compatible with cost-effectiveness principles.
2. Professional acceptance.	Must be aware of only accepting techniques for the purpose they were designed: as a planning tool, not a decision-maker.	Most widely accepted. Broad support largely due to HEP being FWS supported model, not necessarily because it is the best technique. Approach is acceptable, but models must often be developed for specific projects.	Many of those contacted not familiar with method. Widely accepted on regional basis. Accepted equally with HEP by some, others accept hesitantly due to modifications.	Widely accepted on regional basis in bottomland forest habitat. Increasing confidence in technique due to better model documentation. However, HES not widely implemented due to regionalized models.	Accepted as an overview or preliminary approach to determining mitigation needs. Too subjective. Technical limitations. Addresses wetland functions that the other methods do not include.
3. Cost of application.	No general comments.	Most expensive technique to implement. Cost primarily depends on the number of species selected for evaluation. Full effort of 8-10 species per cover type is expensive. Any "short-cut" will be less expensive.	Less costly than HEP. Costs are moderate if appropriate biologic models are available. Computerized approach (GDI/HEP) less labor intensive and therefore less costly.	Moderately expensive. Many have not used HES enough to assess costs.	Least expensive technique. Tries to get a "million dollar study for a buck and a half." Many not familiar enough with WET to assess.

TABLE 4-1

SUMMARY TABLE OF PROFESSIONAL'S REVIEW AND COMMENTS ON HABITAT EVALUATION METHODS

CRITERIA	GENERAL COMMENTS	HEP	PAM HEP	HES	WET
4. Time required for application	Some of the methods conceptually different, therefore you can't really compare time requirements.	Extensive time demands. Labor intensive. Time requirements largely depends on number of species being evaluated. Field work could average 4-6 weeks distributed throughout all seasons. Field work and data analysis most time consuming procedures. New computer model makes HEP less labor intensive.	"Streamlined" HEP. Moderate time demands. Saves an estimated 50-70 percent of the time required to implement the HEP. Field work may take up to 1 week. Cover mapping and data analysis most time consuming tasks. Computer model makes approach even less demanding.	Moderately labor intensive. Takes approximately 1/3-1/2 the time needed to apply a full HEP analysis. Can't "streamline" HES as it must evaluate the entire ecologic community.	Low to moderate time demands.
5. Biological validity	Modelling approaches too different to effectively compare.	HSI's are the most sophisticated biologic models. Biologic models currently being verified. Some models too generalized, or too regionalized. Modifications or development of new models often required.	HSI models used when they are available. Biologic validity has never been challenged. More subjective than HEP. Some of HEP's accuracy has been taken away.	Functional relationship curves relatively accurate. Documentation has increased confidence in validity. Many not familiar enough with HES to comment.	No biologic models used. Only functional capability.
6. Comprehensiveness	Techniques constantly becoming more refined and comprehensive. However, planners must keep their use in perspective. They are still a tool to assist the planner.	Very comprehensive for fish and wildlife resources. Almost universal in its application to all habitats. However modifications to models still necessary. HSI's lacking for many species and regions. Limited to fish and wildlife habitats.	Procedures fairly comprehensive. Some modifications would be necessary for application in other regions. Biologic models would need to be developed when HSI's not available. Many not familiar enough with PAM HEP to comment.	Most comprehensive community-based technique. Developed for Lower Mississippi Valley. Use currently limited to that region. Conceptually comprehensive. Could be modified for use in other regions. Not as comprehensive as HEP, but differences are minimal.	Developed for wetland functions. Fish and wildlife component not as sophisticated as other techniques. More subjective, not data driven. Usefulness in identifying and prioritizing wetland functions.

TABLE 4-1

SUMMARY TABLE OF PROFESSIONAL'S REVIEW AND COMMENTS ON HABITAT EVALUATION METHODS (CONTINUED)

CRITERIA	GENERAL COMMENTS	HEP	PAM HEP	HES	WET
7. Actual application.	None of the methods are difficult to apply when implemented by a trained team. Team approach checks individuals who may attempt to accommodate a bias.	Inter-agency team approach. Team approach balances individual preferences. Requires extensive field data collection. "By the book" approach allows for little professional judgment. Most teams "modify" technique to a degree by using professional judgment. Number crunching and data analysis becoming less burdensome with use of computers.	Inter-agency team approach. Work towards consensus between team members. Uses more professional judgment and visual observations than HEP. Computer software assists in data analysis.	Team or individual approach. Fairly simple to train a biologist to use and apply technique. Moderate field data required. Utilizes professional knowledge and judgment.	Application of technique fairly simple for planner. Does not require extensive field data, or a biologist, but a sound biologic understanding of the study area. Technique uses a series of subjective interpretation keys. Many not familiar enough with WET to comment.
8. Data requirements.	No general comments.	Extensive biologic data required through field collection efforts. Development of HSI models requires detailed information about species.	Moderate data collection efforts required. Relies more on professional knowledge and ocular techniques than HEP. When HSI models are not available they must be developed. This requires more detailed information.	Field data required to develop functional curves. Moderate field data collection efforts required when implementing HES. Many not familiar enough with HES to comment.	Little data required. Requires basic biologic knowledge of the habitat being evaluated.
9. Potential for application to mitigation evaluation.	Techniques are tools to be used by planners in mitigation planning. These tools force planners to look more closely at what is being evaluated. Planners can then make more accurate recommendations.	HEP designed to be used in mitigation planning and evaluation. Potential for good mitigation plans is dependent on the reliability of individual applications. Has ability to focus planner on mitigation needs. It quantifies needs to assist planner in developing mitigation alternatives.	Great potential for mitigation planning and evaluation. Computer model aids in the development and assessment of mitigation alternatives.	Primary purpose of HES is to assess impacts to wildlife and to evaluate mitigation alternatives. Potential for mitigation comparable to HEP. Many not familiar enough with HES to comment.	WET's utility is primarily to assess impacts to wetlands, not to create and evaluate mitigation plans. Not really designed for this. Must be cautious not to force a function that it wasn't designed to perform. Good potential for wetlands creation.

TABLE 4-1

SUMMARY TABLE OF PROFESSIONAL'S REVIEW AND COMMENTS ON HABITAT EVALUATION METHODS
(CONTINUED)

10. Integrability of data with socioeconomic analysis methods.	Impossible to put biological data in straight economic terms. Incremental analysis asks for values. In order to incrementally justify, one must first quantify. Techniques are tools to assist in quantifying.	Has been applied to incremental analysis. Used with cost-effectiveness techniques. HMEM developed based on HEP. Specific mitigation goals must be established in order to integrate with socioeconomic principles. Decision-making up to judgment of the team.	Used with incremental analysis. Capability for tradeoff analysis worked into PAM HEP technique. Team members must understand socioeconomic considerations for appropriate integration.	Has been used with incremental analysis and cost-effectiveness techniques. Many contacts not familiar enough with HES to comment on technique.	Not applicable to economic analysis. Social values which are built into model seem to bias results. Many not familiar enough with technique to comment.

application. However, estimates were made based on an average man-years per acre, or an assessment of the relative time requirements for each method.

Biological Validity

The biological validity of the habitat measurement techniques was reviewed based on the methodology used to incorporate biological considerations into each technique. Biological validity involves four primary aspects: (1) Is each item or factor specified in the measurement technique representative of the biological health and survival of the habitat or species (e.e., the percent of canopy cover for a bird species); (2) Do the specified measurements of that item or factor reasonably relate to the variations in the biological health and survival of the habitat or species (e.g., linear from zero to 1.0 for % cover from zero to 60%); (3) Is that item or factor necessary for the biological health and survival of the habitat or species (e.g., is canopy cover essential for that species of bird); and (4) Is the set of specified measurements sufficient to indicate the biological health and survival of the habitat or species (e.g., the set representing all basic food and reproductive requirements).

Since the scope of this review did not allow for the evaluation of every biological model used, each of the four evaluation techniques was reviewed in general with regard to verification of biological validity by experts in the field. Furthermore, the opinions of the professionals interviewed about the biological validity of each technique were sought. As part of this review, the on-going efforts to improve, refine, further develop and verify the biologic models were discussed and evaluated.

Comprehensiveness

Comprehensiveness of the fish and wildlife measurement techniques involve the methods' ability for application to a wide range of situations. The applicability of the models to various regional environments throughout the country, design limitations of the technique which prohibit or limit its use on some habitats, and its conceptual application were addressed in this evaluation.

Actual Application

A number of examples of the actual application of each of the four mitigation planning evaluation techniques were obtained and reviewed. Applications of the techniques were reviewed in a procedural context as well as from the basis of the tools available for actual applications. The review of procedural requirements included discussion of the use of study objectives, the definition of the study area, and the use of an inter-agency team approach versus an individual approach. The review of tools available to planners for implementing the techniques addressed the availability of computer software packages to simplify and speed data analysis and the actual or potential use of aerial photography in data collection efforts.

Data Requirements

The types and amounts of field data required by each technique for the development of its biologic models or throughout its application were reviewed. Methods of data collection were

addressed as well as the time required to implement the data collection effort. The demands of data processing and analysis for each method were also a component of this analysis.

Potential for Application to Mitigation Planning

An essential element of this review was to assess the ability of the techniques for use in mitigation planning and evaluation as established by COE requirements. This criterion was reviewed through examples of mitigation plans developed based on each of the methods, as well as the observations of professionals familiar with the procedures and the mitigation plans.

Integrability of Data with Socioeconomic Analysis Methods

The ability of the habitat evaluation data and techniques to be integrated with socioeconomic analysis methods is of primary importance to this study. In general, socio-economic analysis involves evaluating the social impacts of a plan, or an increment of a plan, within an economic framework. To the extent to which social impacts (such as impacts on the community and on life, health, safety, long-term productivity or through displacement) are able to be quantified and included in the NED and RED accounts or incorporated in the EQ account, social impacts may be handled through the economic methods described earlier, including benefit-cost analysis, incremental analysis or cost-effectiveness analysis. Otherwise, methods for handling non-quantitative social impacts must be incorporated into the techniques.

The P&G require the consideration of Other Social Effects (OSE) in order to integrate into water resource planning those perspectives that are not reflected in the NED, RED or EQ accounts. These OSE categories include urban and community impacts (ie., income distribution, employment distribution, population distribution and composition, the fiscal condition of the state and local governments, and the quality of community life); life, health and safety factors; displacement; long-term productivity; and energy requirements and energy conservation. Generally, these OSE for alternative plans need not be quantified, but must be displayed in some concise, understandable form for consideration by the decision-maker. However, in this case where economic optimization is sought, the various methods may provide for input of these costs to society along with environmental impacts.

The four mitigation planning evaluation techniques were reviewed under this criterion by considering the ability of each to accommodate the OSE concerns in deciding among mitigation increments and on the final mitigation strategy.

Summary of Comments

The comments in general represent a first-order, in some cases superficial, review of the four habitat evaluation techniques. This level of review was important in establishing a current overview of the most widely used and accepted techniques from the standpoint of the professionals familiar with and/or using the techniques. The level of detail incorporated in Table 4-1 was restricted by the process of aggregating and condensing the remarks and by taking into account obvious biases by some respondents for or against a particular technique. Of particular concern was the comment under criterion #1, concerning the compatibility with accepted economic-ecologic principles, that the respondent was not familiar enough with economic

principles to comment. This indicates that some professionals in the field of mitigation planning are not sensitive to the need to bring economic considerations into their methods.

The comments naturally reflected the primary experience of the professional being interviewed. Most of the persons contacted have had experience with HEP and perhaps one other method. Therefore, many professionals were able to give a comparison between HEP and the one other method with which they were familiar. In general, they accept HEP because it has been the most widely used and documented to date. However, if they have participated in the development of another technique or have used another technique extensively, they would prefer the other technique rather than HEP. The reason most often given was the expense and time required to conduct a HEP analysis. Those who have used PAM HEP are enthusiastic in that they believe it retains the basic ecological principles of HEP while decreasing the time and expense considerably. Those who have used HES stress its community basis versus the species basis of HEP, although both techniques rely on many of the same actual field measurements. Those who have used WET stress its ease and rapidity of use for projects impacting on wetlands.

COMPARISON OF HABITAT EVALUATION METHODS

Based on the study team review of each mitigation evaluation technique, interviews with professionals in the field, and a review of appropriate literature (see Appendix D), a critical, in-depth review of the habitat evaluation techniques was performed. An overview of the findings from this research is provided in Table 4-2. As in Table 4-1, the findings have been aggregated and condensed to provide a convenient summary overview table.

Compatibility with Accepted Economic-Ecologic Evaluation Principles

Habitat-based approaches: All four of the techniques being evaluated are habitat-based evaluation procedures, which is the approach most widely accepted as providing the most appropriate and valid appraisal of fish and wildlife resources. HEP and PAM HEP are both species-based habitat evaluation techniques, which bases the evaluation of the entire habitat on a representative group of selected species. HES and WET are ecologic community-based habitat evaluation methods. This approach measures the community's ability to carry and support species through an inventory and analysis of the flora and fauna within the study area.

TABLE 4-2
COMPARISON OF HABITAT EVALUATION METHODS

CRITERIA	HEP	PAM HEP	HES	WET
1. Compatibility with accepted economic/ecologic evaluation principles.				
a. Habitat-based procedures	Species-based habitat evaluation approach.	Species-based habitat evaluation approach. Modification of HEP.	Community-based habitat evaluation approach.	Community-based habitat evaluation approach.
b. Incremental analysis	Compatible with incremental analysis.	Compatible with incremental analysis.	Compatible with incremental analysis.	Not compatible with incremental analysis.
c. Cost-effectiveness	Compatible with cost-effectiveness.	Compatible with cost-effectiveness.	Compatible with cost-effectiveness.	Compatible with cost-effectiveness.
2. Professional acceptance				
a. Conceptual acceptance	Generally accepted. Some concern regarding the ability of selected species to represent entire habitat.	Varying degrees of acceptance. Some feel modifications have compromised HEP, others feel they have not affected final results.	High level of conceptual acceptance.	Not highly accepted for use in fish and wildlife applications.
b. Implementable	Procedures widely accepted.	Well developed procedures for implementation. Accounting procedures have been streamlined.	Well developed procedures which could be used nationwide if biologic models were available.	Implementation too subjective.
3. Cost of application				
a. Major factors relevant to cost	Dependent on number of species selected for evaluation; size of study area; availability of HSI's; number of team members.	Number of species selected for evaluation; size of study area; availability of HSI's; number of team members.	Size of study area; availability ot functional models (HQI's); number of team members.	Size of study area; biologic knowledge of planner about area and amount of previously acquired information on area.
b. Average cost per acre	Not available.	Not available.	Not available.	Not available.
c. Average number of man years per acre	Not available.	Not available.	Not available.	Not available.
d. Most costly components	Data collection; data analysis.	Mapping cover areas; data collection and analysis.	Data analysis.	Field collection when necessary.

TABLE 4-2
COMPARISON OF HABITAT EVALUATION METHODS
(CONTINUED)

CRITERIA	HEP	PAM HEP	HES	WET
4. Time required for application				
a. Major factors relevant to time	Number of species selected for evaluation; size of study area; availability of HSI's; number of team members.	Number of species selected for evaluation; size of study area; availability of HSI's; number of team members; use of computer.	Size of study area; availability of HQI's; number of individuals involved with study.	Size of study area; the need for data collection (dependent on available historical information).
b. Average man-years per acre	Not available.	Not available.	Not available.	Not available.
c. Estimate of average time for application	6 months to 1 year for completion.	1 month to 3 months for completion.	2 months to 4 months for completion.	2 days to 1 week.
d. Relative time requirements	Most labor intensive approach.	Two to three times quicker than HEP.	Takes about half as much time as HEP.	
5. Biological validity				
a. Biologic measurement tool	HSI models and HU's. (HSI value x acreage = HU).	HSI models and HU's. More subjective measurement than HEP. PAM HEP recently updated with computer software.	Use of functional curves (HQI's) to determine Habitat Unit Values.	No biologic measurement tool.
b. Status of research	HSI's currently being verified. Research will then resume in developing new models. Models developed on field level when needed.	No specific research to refine procedures.	Recently refined and updated. No additional research in progress.	WES currently refining procedures.
6. Comprehensiveness				
a. National/regional application	Used nationwide, however, HSI's must be developed and modified for specific projects.	Used in Pennsylvania and some use in a couple of neighboring states with similar habitat.	Regional application to bottomlands of Lower Mississippi Valley region.	Nationwide application.
b. Design limitations.	Limited to fish and wildlife applications.	Limited to fish and wildlife applications.	Biologic models designed for one specific habitat.	Limited to wetland functions.
c. Use in COE planning projects	Flood protection; navigation; water supply studies; permit applications.	Flood protection; navigation; water supply studies; permit applications.	Flood protection; navigation;	Used in preliminary phases of water supply studies; permit applications.

TABLE 4-2
COMPARISON OF HABITAT EVALUATION METHODS
(CONTINUED)

CRITERIA	HEP	PAM HEP	HES	WET
7. Actual application				
a. Team v. individual implementation	Inter-agency team approach required.	Inter-agency team approach required.	Not specified.	Not specified.
b. Availability of software package	Computer software aids in data analysis and mitigation evaluation.	Computer software (GDI/HEP) adds in data analysis and mitigation evaluation.	Software available to aid in data analysis.	Most recent version of technique is computer generated.
c. Use of previously collected data	HSI's available for use. Previously collected data not recommended.	HSI models used. Previously recorded useful.	HQI's available for bottomland habitat. Previously collected data useful in determining subjective judgments.	Subjective judgments based on previous knowledge of study area.
d. Use of aerial photography	Aerial photography useful in defining cover types.	Aerial photography useful in defining cover types.	Aerial photography useful.	Aerial photography not used.
8. Data requirements				
a. Methods of data collection	Field data collection required for selected species. Team approach utilized.	Field data collection; use of professional judgment. Team approach utilized.	Field data collection; use of professional judgment.	Site visit required. Field data not usually required.
b. Time demands of data collection	Average of 2-4 months for data collection efforts.	Average of 1 week required for data collection.	Average of 1-2 weeks required for data collection.	Not applicable.
c. Time demands of data analysis	Average of 6-8 months for data analysis.	Average of 1-2 months needed for data analysis.	Average of 1-3 months for data analysis.	One day needed for subjective data analysis.

TABLE 4-2
COMPARISON OF HABITAT EVALUATION METHODS
(CONTINUED)

CRITERIA	HEP	PAM HEP	HES	WET
9. Potential for application to mitigation planning.				
a. Designed for development of mitigation alternatives?	Yes. HU's indicate impacts to habitat and the establishment of mitigation objectives guides in the level of mitigation.	Yes. HU's indicate impacts to habitat and the establishment of mitigation objectives guides in the level of mitigation.	Yes. HUV's indicate impacts to habitat and the establishment of mitigation objectives guides in the level of mitigation.	WET useful in mitigation plan development especially for wetlands creation.
b. Useful in mitigation evaluation?	Yes. Procedure assists in evaluating alternatives by assessing impact of mitigation in terms of HU's compensated.	Yes. Procedure assists in evaluating alternatives by assessing impact of mitigation in terms of HU's compensated.	Yes. Procedure assists in evaluating alternatives by assessing impact of mitigation in terms of HUV's compensated.	Provides subjective evaluation of mitigation plans.
10. Integrability of data with socioeconmic analysis techniques				
a. Social concerns incorporated in model	Relative Value Indices (RVI) designed for HEP. Considers social importance of species.	Consideration of socially significant species during species selection.	No specific reference to social concerns in procedures.	Predictor keys provides for consideration of social values and concerns.
b. Integration with economic analysis techniques	Has been integrated with incremental analysis and cost-effectiveness techniques in the analysis of mitigation alternatives.	Has been integrated with incremental analysis and cost-effectiveness techniques in the analysis of mitigation alternatives.	Has been integrated with incremental analysis and cost-effectiveness techniques in the analysis of mitigation alternatives.	Can be integrated for use in the selection of most cost-effective alternative.

Many feel that conceptually, the community-based approach is preferred, particularly in cases where high species diversity or richness is valued. Many federal agencies are currently stressing species diversity as being important for habitat health and resilience as well as for overall social welfare. However, the habitat-based approach is in many cases more difficult to quantify objectively than a species-based approach. Too much subjectivity is an often mentioned criticism of HES and WET, with WET considered to be the most subjective technique of all. Users of these models, especially HES, contend that their background and expertise compensate for whatever additional subjectivity there may be in HES, and in the final evaluation, a better mitigation plan can be developed from using a community-based approach. At this point, however, community-based models for HES have only been developed for one habitat region within this country. Therefore, HES is not widely used. WET is widely used by the U. S. Department of Transportation for evaluating the impact of proposed highways on wetlands.

Incremental cost analysis: Incremental cost analysis is the current COE accepted economic method. In order to prepare an incremental analysis, the measurement techniques must have the potential for developing mitigation plans from a series of incremental components which can be ranked from most to least cost-effective. Three of the measurement techniques, HEP, PAM HEP, and HES utilize a standard habitat unit of measurement to assess without- and with-project induced losses to fish and wildlife resources and gains to these resources associated with mitigation measures. Each of these measures can be incrementally justified. Therefore, HEP, PAM HEP, and HES are compatible with incremental analysis. WET, which utilizes functional relationships rather than quantitative measurements, is not compatible with such an incremental analysis.

Cost-effectiveness: All four of the techniques are compatible with the cost-effectiveness approach to mitigation planning.

Bioeconomic models: HEP, PAM HEP and HES can conceivably all be used in such models, except perhaps the energy models, since all can provide quantitative measures of species and/or habitat responses to without and with project conditions which can be entered into the models.

Professional Acceptance

HEP is the most accepted method currently available for the measurement and evaluation of fish and wildlife resources. Largely due to its prominence as the technique developed and supported by the FWS, and the requirement for COE-FWS interaction, use of HEP has spread rapidly throughout FWS field and COE district offices. Biologists became trained and experienced in HEP, and in many instances it has been used without consideration of availability of other alternative techniques. HEP is also widely accepted for its objective approach to habitat evaluation and for the precision and accuracy of its HSI models. Since almost everyone involved with habitat measurement and evaluation is familiar with HEP, it became a standard of comparison for the other techniques throughout this review.

In a more limited sense, the other techniques are also accepted by biologists. For instance, HES, a community-based approach to habitat evaluation, is often referred to as conceptually the best approach. Although criticism can be heard about the validity of its biologic models and the very limited regional scope of the models, several of those contacted felt that the ecologic

premise of HES is fundamentally more able to give an accurate measurement of fish and wildlife resources than HEP or other species-based approaches. HES is also widely accepted in the Lower Mississippi Valley, the region for which the technique was originally designed.

PAM HEP is a technique also accepted on a limited basis. Generally, it is felt that if more users outside of Pennsylvania were aware of PAM HEP, it would be more widely used and accepted. Some biologists contend, however, that PAM HEP has compromised the biologic validity of HEP's HSI models through changes in sampling and accounting procedures. For this reason, they do not feel PAM HEP is an acceptable technique. However, users of PAM HEP believe that mitigation planning is not significantly affected by the differences in sampling and accounting techniques and, with a few minor procedural changes, has the potential of being a widely used and accepted alternative to HEP. As noted above, the increased computerization of PAM HEP (GDI HEP) versus HEP and HES may also lead to its increased professional acceptance and use.

WET is the least accepted technique for the measurement of fish and wildlife resources. WET is considered to be too subjective in its application to fish and wildlife measurements. Even the developers of WET acknowledge validity in this criticism, and are quick to add that the fish and wildlife component of WET received the least attention during design stages due to the availability of HEP, HES, and other measurement techniques. However, WET is widely used by the U.S. Department of Transportation, Federal Highway Administration (DOT-FHWA) for wetlands impacted by proposed highway projects, and are supporting the current development of WET II.

Cost of Application

The cost of application for all of the techniques being evaluated is dependent on several factors. HEP is regarded as the most costly technique for habitat evaluation, but is largely dependent on the number of species selected for assessment and the amount of field data required. The HEP Manual (Ecological Services Manual--Habitat Evaluation Procedures, FWS 1980) provides some general guidelines for planners to estimate cost for a HEP application in terms of its time requirements, as follows:

> "A detailed water resource study, consisting of a manual application of HEP that considers 3 proposed actions, 20 evaluation species, 5 cover types, and a total area of 20,000 acres, would require approximately 70 to 110 work days according to the guidelines presented in this chapter. A computer assisted application would reduce this time by 12 to 21 days."

None of the users manuals for the techniques other than HEP provides any guidelines to help planners estimate a cost of application. Those contacted were able to provide a review of costs, but only in relation to HEP. For instance, according to users, PAM HEP requires less than half the cost of HEP. This is primarily because of the differences in data collection requirements and data analysis methods. In addition, most individuals familiar with HES generally agree that this technique would probably cost about half of a HEP application. WET is acknowledged as the least costly habitat evaluation technique. As described by one contact, WET is to get a million dollar study for a buck-and-a-half.

Time Required for Application

The time requirements for application go hand-in-hand with the cost of application. For HEP, time requirements are dependent on pre-field costs, field costs, and the analysis of data as discussed in the HEP Manual and presented in this review under Cost of Application. The time demands of a HEP are a major concern of its users. Users from the St. Paul District COE discussed this concern about HEP:

> "Our experience has been that time will generally be more restrictive than cost will be. This may be a reflection of our location in a northern climate where the field season for data collection is limited and does not always mesh with project schedules. We will have difficulty completing a HEP study for a major feasibility study within the new 18-month limit for feasibility studies." (Palesh, et al., 1987).

Most of the individuals contacted concur that the time requirements demanded by HEP can be a prohibitive factor. Partially in response to this concern, PAM HEP was developed. Modifications to field data accounting procedures and data analysis methodology have resulted in a more streamlined approach. Developers of PAM HEP (GDI HEP) contend that it can save up to 70 percent of the time required by HEP. They also acknowledge that the cost of this savings in time is a degree of biologic precision and accuracy.

The HES Manual provides a vague description of the time required for application. It states, Use of HES is rapid and efficient and requires a minimum of field and laboratory data in terrestrial habitats, many of the variable values can be quickly made by visual estimates. Data for most aquatic functional curves can be obtained from historical data sources. (HES: A Habitat Evaluation System for Water Resources Planning, Lower Mississippi Valley Division, COE, 1980.) Most of those familiar with HES feel that a HES application could be completed within four to six months of its start.

WET is considered to be the least time demanding application. The method relies primarily on subjective judgments and historical data, and requires, on the average, only two days for field data collection. Applications requiring longer data collection efforts are mostly due to an increase in travel time, not actual field work. After the relevant data are collected, the methodology requires one day maximum for data analysis.

Biological Validity

A comparison of the biological validity of the models is difficult to make. This is due to the conceptual differences between the approaches. The species-based HEP HSI models have been the most researched and developed models. The HSI models are developed for single species in a particular habitat, two or more of which are used as indicators for the entire habitat. The more than 100 HSI models which are currently available have been field-validated in roughly 40 cases, and more are currently being validated by various methods, including field application. Developers of PAM HEP, with their streamlined modifications, have attempted to maintain biological validity by using the HSI models when and where available. The modifications implemented by PAM HEP have been said to have compromised the biologic validity to a degree, but proponents feel not significantly enough to make a real difference in results.

HES has been developed to date primarily for use in the Lower Mississippi Valley. The functional curves developed for HES have also recently undergone a validation process which has increased confidence in their usefulness. When used in the habitats for which they have been designed, there is general agreement that HES is biologically sound.

WET method lacks a primary biological validity in its subjective approach to habitat evaluation. No clear attempt is made to measure impacts to habitat through models, but rather the technique evaluates wetland functions to be impacted through subjective predictor keys. On the other hand, the predictors are intended to predict project impacts on wetland functional values. The 75 predictors are strongly related to fundamental biological processes in wetland habitats. Also, the questions to be answered about each predictor are intended to guide the biologist and other evaluation team members into determining the primary biological (and other) impacts of the without- and with-project conditions on the wetland habitat. Therefore, WET must be considered to be based on the overt use of professional, subjective evaluation of biological functions.

In summary, all four techniques have an innate subjectivity in determining their biological validity, although HEP, PAM HEP and HES rely on extensive biological models to relate field measurements and observations to quantitative habitat units. WET relies directly on subjective judgments of biological functions, Thus the biological validity depends ultimately on the skill of the biologists and other team members developing the models and conducting the field observations.

<u>Comprehensiveness</u>

Comprehensiveness is being defined by the review of the techniques' ability for use in applications in a variety of situations. Table 4-3 provides a summary of these findings.

<u>Data Requirements</u>

HEP is the most data demanding of the measurement techniques being evaluated. After the study area has been delineated, a group of representative species must be selected for each cover type. Guilding is one approach used in the species selection process which considers factors such as feeding modes, nesting requirements, and breeding habitats, and is suggested in HEP Manual.

A major difference between HEP and PAM HEP is in the data requirements, in particular, the number of sample plots. PAM HEP relies on more subjective judgment by biologists, relieving the team of much of the time-consuming field collection activities.

Data requirements with HES begin with defining the study area. Key variables are determined within each ecosystem of the area and data on these variables is collected for analysis. Data collection efforts typically are more subjective, utilizing a visual review of the area and the biologist's understanding of the habitat. Each variable is weighted according to predetermined biological considerations.

WET is the least data driven of the four measurement techniques. It is highly suggested that a site visit of the study area be made in order to become visually familiar with the habitat,

	HEP	PAM HEP	HES	WET
Applicable nationally?	YES	Not yet	NO	YES
Modifications necessary for national applications?	NO	Minor Procedural Changes	Development of additional regional models	NO
Applicable to flood control projects?	YES	YES	YES	YES
Applicable to navigation projects?	YES	YES	YES	YES
Comprehensive use for fish and wildlife applications?	YES	YES	YES	NO

Table 4-3: Comprehensiveness of Measurement Techniques

but except for situations out of the ordinary, field data collection is not required. WET relies on historical information and previously collected data when subjective judgments need support from more specific data.

Potential for Application to Mitigation Evaluation

Each of the measurement techniques being evaluated were designed for use in mitigation plan development and analysis. However, for use in fish and wildlife resource applications, WET is the least desirable technique. HEP, HES, and PAM HEP have all been applied to mitigation planning of fish and wildlife resources.

Integrability of Data with Socioeconomic Analysis Methods

Socioeconomic considerations can be included in mitigation plan development and evaluation through defining appropriate mitigation planning objectives, trade-off analysis, or social significance functions. For instance, mitigation objectives may require in-kind replacement of socioeconomically valuable species, habitats or resources such as deer, pheasant or trout. As noted above, the HEP procedures allow for the selection of indicator species that have high public interest, economic value or both.

Similarities in comprehensiveness of the techniques exist in their applicability to water resources projects. All four evaluation methods have the ability to be used for all water resource projects, including flood control and navigation studies. Other than WET, they are also integrable for use in fish and wildlife applications. The fish and wildlife component of WET is the component least developed, and, therefore, except in low-budget applications, or for use as a preliminary tool, is not comprehensive enough for sole use in a COE water resources planning effort.

Actual Application

Examples of actual applications to specific projects are listed in Appendix A, and additional examples may be found in the Bibliography, Appendix D.

Several components of actual application were evaluated for each of the methods in addressing this criterion. Table 4-4 summarizes the findings of this review.

HEP and PAM HEP make provision for a trade-off analysis when considering the compensatory mitigation of unlike habitats, for instance streams versus woods. This trade-off analysis depends upon multiplying the habitat units for each species by a relative value index (RVI). The RVI is determined subjectively by the study team based on the perceived social significance or economic value of that species. The resulting habitat units then reflect a judgment which permits the mitigation planning team to trade-off HU's for different species within and among different habitats.

WET makes provision for incorporating a social significance for each habitat function. This method involves answering seventy-seven questions (Form B) with regard to the general and specific significance of the project and its impacts on the wetland. The method is entirely subjective, but recognizes the importance of social acceptability of the project and its mitigation measures.

The decision as to how to aim the study and mitigation plan is often basically philosophical, social or even political as well as economic. Given the underlying subjectivity of all of the techniques, socio-economic concerns can be entered in many ways and the data can be integrated into the overall socioeconomic framework using any one of the four techniques. In addition, the P&G require that the non-quantitative social aspects of a project which cannot be included in the NED, RED and EQ accounts, must be considered under the OSE account, and the results displayed for the decision-maker to consider. All four of the techniques are compatible with this requirement.

FIELD COMPARISON

HEP versus HES: (The Red River Waterway Project)

The final report and environmental impact statement for the Red River Waterway Project dealt fairly extensively with the question of mitigation for unavoidable wildlife losses. The New Orleans District, COE used two methods in estimating project-related wildlife losses - the Habitat Evaluation System (HES) and a User-Day/Monetary analysis. The User-Day/Monetary analysis, which evaluates the project-induced user-day and monetary losses and gains, was found to be inadequate because it only accounted for tangible wildlife related values such as hunting and bird watching and, thus reflected less mitigation needs than the two habitat-based analyses. The FWS implemented the second habitat-based analyses by calculating the losses using the Habitat Evaluation Procedure (HEP).

The review of the comparison between HES and HEP analyses for the Red River Waterway Project is best presented through the following excerpt from the study. The report, prepared by

	HEP	PAM HEP	HES	WET
Team Approach Required	YES	YES	NO	NO
Training Required	YES	YES	YES	YES
Define Mitigation Objectives	YES	YES	YES	YES
Define Study Area	YES	YES	YES	YES
Select Representative Species	YES	YES	NO	NO
Data Collection Required	Extensive	Moderate	Moderate	Low
Use of Judgement	YES	YES	YES	YES
Computer Software Available	YES	YES	YES	YES

Table 4-4: Application Characteristics of Techniques

the New Orleans District, COE in September 1983, is entitled, Red River Waterway LA., TEX., ARK., and OKLA. Mississippi River to Shreveport, LA.-Final Report and Final Environmental Impact Statement for Acquisition of Wildlife Mitigation Lands.

> "Mitigation needs are more accurately reflected in the habitat-based analyses in that they not only account for losses to hunting and wildlife oriented recreation, but also for intangibles. Generally, the Corps and FWS agreed on methodology and critical matters where professional judgement was required. Considering that the two habitat-based analyses have many dissimilarities, it is significant that, on a project of this magnitude, land acquisition requirements based on HES and HEP were 14,280 and 14,577 acres respectively. It should be noted, however, that HES acreage was based solely on acquisition and management of bottomland hardwoods and HEP acreage was based mostly on bottomland hardwoods with some mix of openlands and swamps."

This comparative effort seems to have provided planners with one basic observation. Both methods indicate that land acquisition is required, and that acreage needs are quite similar. Although land use plans for the acquired acreage would be different, the small difference in required acquisition recommended by HEP and HES remains a significant observation. This does not say that the two methods are equivalent, but perhaps adds some validity and confidence to each of the techniques. Of course it would require a major study effort focusing on the comparison of fish and wildlife measurement techniques before any sound conclusions could be drawn.

COMPATIBILITY WITH COE MITIGATION PLANNING

Compatibility in the current context refers specifically to compatibility with the incremental analysis of mitigation efforts as defined by current COE guidance and policy.

HEP

HEP is the most comprehensive species-oriented approach to habitat evaluation available today. Its biologic validity is supported by its extensive model development and verification process, as well as the intense data requirements in the application of the procedure. The thoroughness of this technique does not come freely, as it is the most time-consuming and most expensive to implement. Because of this, its suitability is greater for larger (COE) projects than it is for smaller projects or state agency habitat evaluations.

The inter-agency approach used by HEP encourages consensus between the representatives of various agencies, including FWS, National Park Service, and various state and local agencies, as well as the COE. Assuming each team member is properly representing his agency's mitigation policy, in theory, the final recommendation of the team should be satisfactory to agency decision-makers. Often, this team approach is used to determine the recommended plan and, based on the most cost-effective use of mitigation measures, to achieve some goal established by the agencies as the appropriate level of mitigation.

Because HEP has gained prominence as the FWS accepted procedure for habitat evaluation, it is the most widely used and accepted method for environmental quantifications. Many users are not familiar with other methods and continue to use HEP out of experience and habit. HEP has been streamlined in many instances to fit individual needs and, therefore, HEP is rarely applied in its entirety.

The major constraint of HEP is in its basic premise that an entire habitat can be evaluated based on a few representative species. Such an approach avoids the complex interrelationships which are characteristics of biophysical systems. Further research into the interdependence of species will be instrumental in determining the validity of this species-based approach to habitat evaluation and mitigation planning.

As previously stated, the most effective use of HEP is with projects large in size, scope, and social importance. Often, COE planning projects tend to have the time and budget available to perform a HEP analysis and require the precision afforded by its biologic models. Smaller projects can certainly benefit from the accuracy provided by HEP, but the time and cost associated with the procedures are often prohibitive and have encouraged the development of modifications, such as PAM HEP.

HEP is particularly applicable to mitigation planning because it uses HU's to provide a common denominator to use in determining project impacts on habitat. The differences in habitat units between the without- and with-project futures becomes the basis for mitigation plans which attempt to combine available measures, either to increase the suitability of the habitat through management and ultimately increase its HSI value, or acquisition of additional acreage to

preserve or enhance its habitat value. Either way, the concept of mitigation is to select a plan which will make up for the lost HU's in the least costly manner.

PAM HEP

Although PAM HEP is closely associated with HEP, its procedures have been modified extensively enough to give PAM HEP its own unique approach to habitat measurement. These modifications, however, have created a dispute over the use of this method. Opponents feel that this streamlined approach has come at the expense of accuracy and precision of the habitat evaluation. Proponents acknowledge that the technique does sacrifice these qualities to some degree, but feel that the relatively low degree of accuracy given up is justified by the savings in time and expense. They also feel that the mitigation plans derived from using PAM HEP are not adversely affected by the modifications, so the plans are just as effective as those developed with HEP. Currently, PAM HEP is primarily in use in Pennsylvania and New Jersey, with a few projects to date in several other states. The procedures can easily be adapted for other regions.

Savings in time from using PAM HEP instead of HEP have been estimated at 50 to 70 percent. These time savings are mostly due to the less intense data collection effort and the computer software which simplifies the data analysis and documentation. The size of the study area, the availability of the biologic models, and the number of individuals comprising the interagency team are among the significant elements affecting time and cost of project implementation.

The biological validity of PAM HEP is based on the widely accepted HSI models, developed for HEP. By maintaining the use of the HSI's in the procedure, developers of PAM HEP feel they have preserved the strengths and validity of HEP.

The most efficient use of PAM HEP seems to be with smaller scale projects, characterized by limited budgets and time constraints. The procedure would provide not only a well documented and systematic approach to determining impacts to habitat and mitigation needs, but also a biologically sound model at a much more affordable cost.

PAM HEP has the ability to assist in the development and evaluation of mitigation plans. Mitigation plans can be developed by assessing the number of habitat units needed to compensate for the proposed project and used to establish mitigation goals. Mitigation measures such as land acquisition and/or management can then be used to compensate a specific number of habitat units. By combining these mitigation measures, mitigation plans can be selected that will best meet the mitigation objectives for the least cost.

HES

HES is the most widely accepted community-based approach to habitat evaluation. Although currently it can not be universally applied, many of those interviewed contend that conceptually, it has the potential for being a widely used approach with substantial biological validity. Use of HES has been limited by the scarcity of biologic models or functional curves, known as HQI's, as they have only been developed for the bottomlands of the Lower Mississippi Valley region.

The cost of a HES evaluation is largely defined by the size of the study area, with data collection efforts constituting a large portion of the needed time and cost of the application. Relative to the other techniques being evaluated, HES is not as labor intensive to implement as HEP, requiring an average of two to four months, but more intensive than PAM HEP or WET. HES procedures can be conducted by one individual or as a team effort with varying costs dependent on which approach is selected for implementation.

Increasing confidence has been established in the HES biologic models as they are used and refined. Both the COE, through efforts at the Waterways Experiment Station and Lower Mississippi Vally Division office, and FWS, through its National Ecology Research Center in Fort Collins are involved in research efforts to enhance the existing HES models for bottomland hardwood areas.

Similar to HEP and PAM HEP, HES was originally designed for mitigation planning purposes. The end result of a HES analysis is the number of Habitat Unit Values (HUV's) changed with the implementation of a project. This change represents the impact of the project and determines what mitigation is required and is a measure of the mitigation goal. Mitigation plans can then be developed and evaluated by assessing the number of HUV's compensated by each mitigation measure. These measures can then be combined in a way that will best achieve the mitigation plan or compensate the number of HUV's that are required by mitigation objectives.

WET

Based on this review, WET is the least acceptable approach to habitat evaluation and mitigation planning. Research continues in an effort to make WET more practical as a mitigation planning tool, and a joint project between the COE Waterways Experiment Station and the New England District is intended to examine its usefulness in this capacity. For now, WET is still in a developing phase, but its developers feel it is on track to becoming a significantly useful tool which eventually could be used in mitigation planning.

Overall, WET is viewed as a preliminary approach to evaluating wetland habitats. In regards to fish and wildlife, it is acknowledged that WET is not as sophisticated nor biologically valid as HEP, HES, or PAM HEP. Because of WET's subjectivity, it is not able to provide a precise measurement of habitat requirements, but does offer a prioritized assessment of mitigation needs. This system is not without merit, especially in the area of wetlands creation as a mitigation alternative.

Attractive qualities of WET include its relative low expensive and minimal time demands. WET's software can be implemented by a single individual with little effort to assess project-induced impacts and mitigation needs. A WET evaluation can be implemented in one day when data on a study area are readily available, or a maximum of two weeks if data collection is required. A basic, sound biological knowledge of the study area is essential, but extensive data gathering is not required. Of course, this also reflects on the lesser degree of biological validity of the method.

It can be concluded that WET is compatible with the currently accepted emphasis on a habitat-based evaluation. However, examples of its integration with socioeconomic analysis methods were not found, and no detailed assessment of its effectiveness in the evaluation of mitigation alternatives was made. Developers of WET acknowledge it does leave a void for planners in the area of economic analysis; however, research is currently attempting to incorporate these concerns into the model.

SUMMARY COMMENTS

Each of the four evaluation techniques has been found to be useful and valid within the context of its origins and development. Clearly the biological validity of the HSI's in HEP and PAM HEP, and the HQI's in HES must continue to be proven in each habitat under evaluation, and the number of biological models extended to include all species or habitats likely to be impacted by proposed projects. Figure 4-1 provides a final overview of the applicability of these methods to COE mitigation planning.

It is also apparent that habitat evaluation procedures which are less complex and require less time, effort, and funds than HEP but which are still biologically valid, must be developed. In this regard, the extension in the use of HES and PAM HEP to other regions of the country would appear to be most promising. To ensure the applicability of HES and PAM HEP to other regions of the U.S., a number of comparison studies with HEP should be conducted.

WET would be more useful for incremental cost analysis for mitigation if it were improved to provide more quantitative modeling of outputs from management plans.

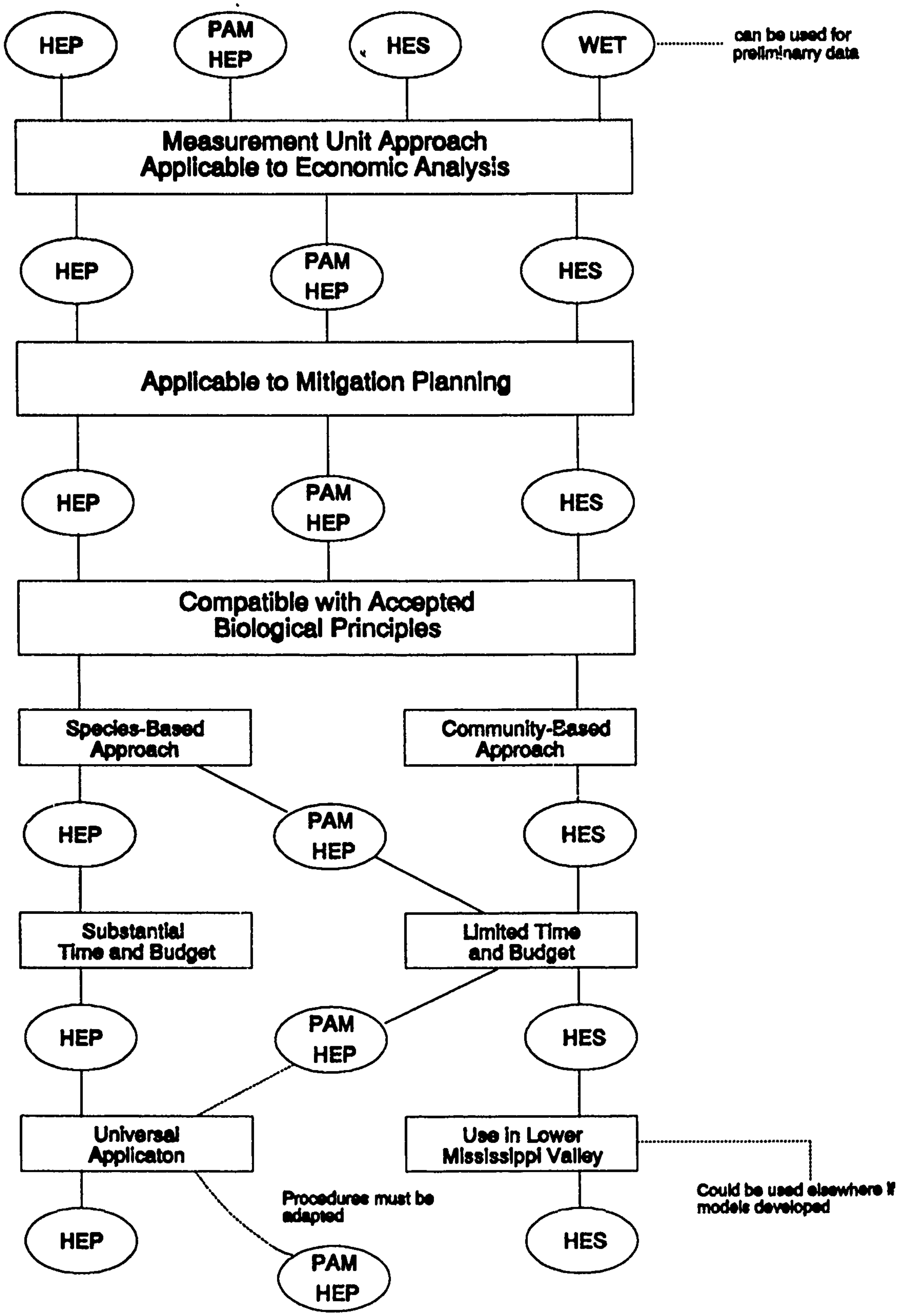

Figure 4-1: Fish and Wildlife Measurement Techniques Applicable to COE Incremental Mitigation Plannin

CHAPTER 5

CONCEPTUAL MODELS FOR INCREMENTAL MITIGATION PLANNING

WHAT IS NEEDED

It has been pointed out and emphasized that mitigation planning requires measurement of the habitat in some quantifiable manner based on both its quality and quantity. Also, some mechanism must be available to evaluate the ability of management measures to substitute for lost habitat. The concept of the habitat unit (HU) associated with HEP and PAM HEP, and habitat unit values (HUV) associated with HES provides a standard reference unit for such habitat measurements. Since these units are a product of both quantity (habitat acreage) and quality (HSI or HQI), habitat lost to, or impacted by, a project can be mitigated in increments up to 100 percent either by replacing the lost acreage or by introducing measures to increase the ability of the habitat to support the impacted species. Therefore, HEP, PAM HEP and HES are conceptually appropriate measurement techniques applicable to incremental mitigation planning.

What remains is to develop some mechanism to assemble different management measures into separable, cost-effective plans that achieve various mitigation goals up to 100 percent mitigation. The result is intended to be a cost/mitigation tradeoff curve that can serve as an aid in determining the appropriate level of mitigation.

Currently, there are two promising conceptual approaches that have been developed for this purpose, biophysical response modeling (BRM) and habitat management evaluation model (HMEM).

BIOPHYSICAL RESPONSE MODELING

Since mitigation represents a classic optimization problem, many attempts have been made to use linear programming (LP) techniques for mitigation planning. In 1982, the U. S. Bureau of Reclamation and the Agricultural Economics Department at Washington State University developed an LP model to formulate mitigation plans for the Garrison Diversion Project in North Dakota. HEP habitat suitability indices (HSI's) were used to develop production functions that were used as the constraints for this model. These constraints showed the quantity of various habitat types required to produce a particular HU. In order to evaluate the minimum costs of various levels of mitigation up to 100 percent, the minimum values of the HU's requiring mitigation were varied up to 100 percent. The output of HU's was a direct function of the acreage of the various habitat types. In other words, the quantity of land was used as the variable.

Such a model is only useful in mitigation planning if land acquisition is the measure being considered. However, frequently the more appropriate way, or the only way, to approach mitigation is through management measures designed to increase the quality of habitats. This would require the model to calculate the biological response to management measures by calculating increases in HSI or HQI values. Since many biological and physical processes are

inherently non-linear, this would necessitate a non-linear model and an understanding of the non-linear interactions.

In 1986, Matulich and Hanson developed a model using piece-wise linear programming to minimize the cost of managing wildlife areas for mallard ducks and pheasant in the Columbia River basin. The combination of the pieces represented an overall non-linear response. Their model consisted of four primary components that comprise the constraint function:

(1) a biological production model linked to habitat management activities;
(2) physical resources that define the particular environmental setting;
(3) pertinent political or institutional constraints that limit or otherwise dictate essential measurement practices; and
(4) an overall biological production goal (expressed in the number of habitat units).

The heart of the model is biological response submodels which are based on the HEP HSI and which are linked to management practices or activities to yield a response surface. The output of the model gave enhancement/management costs as a function of the intensity with which the activities must be applied to achieve a given HU goal. Matulich and Hanson were successful in using this approach to develop minimum management costs at various levels in the production of mallard duck and pheasant HU's. These were used to calculate a minimum cost curve.

Although biophysical response modeling seems promising at the conceptual level, there are a number of practical problems with its application to mitigation planning. Developing piece-wise linear functions to represent non-linear functions greatly increases the necessary computations. Matulich and Hanson required 1,606 variables and 492 equations for just two species. The effort and expense associated with such a procedure limits the application of biophysical response modeling, especially for small projects with short time frames and particularly for those projects which impact on several species. Furthermore, the automated black box nature of the LP optimization routines may make the selected plans suspect by the decision-maker.

Some of the computational and conceptual problems with the piece-wise LP approach could possibly be overcome with direct non-linear programming. However, the development of the required biophysical response functions is very complex and understood for few if any combinations of species and habitats. Also, non-linear models frequently yield multiple optima, so that an initial guess as to the likely optimum is needed as an input to the model.

HABITAT MANAGEMENT EVALUATION MODEL (HMEM)

HMEM is an interactive, menu-driven computer program developed by the Office of Environmental Technical Services of the Bureau of Reclamation and the National Ecology Center (NEC) of the Fish and Wildlife Service to assist in the formulation of cost-effective mitigation plans. The program entails users to develop incremental plans to meet mitigation goals and measures the cost of the management required to achieve the specified number of habitat units (HU).

The underlying principle behind HMEM is the concept of cost-effectiveness as expressed by (1) the cost of management, and (2) the effectiveness of management. HMEM links the HSI

software of HEP to management action models that are mathematical equations describing how a particular management action affects specific habitat model variables. Then, with entered cost information, HMEM computes the effectiveness of the management measures in terms of dollars per habitat unit ($/HU). By developing this relationship, the program rapidly provides an analysis of the effects of multiple activities on selected evaluation species. With this information, the user can explore alternative management strategies through successive trials to formulate alternative cost-effective plans achieving different levels of mitigation (HU's).

HMEM is a decision support system and provides guidance on how to combine the most cost-effective activities into an overall plan through incremental cost analysis. It is <u>not</u> an optimization technique because it does not find the absolute minimum cost plan and it does <u>not</u> make decisions. Nevertheless, HMEM is useful in mitigation planning because it will produce the required mitigation cost curve. HMEM is relatively easy to operate and use, and has been designed for use at the field level. The model runs by creating and storing management equations combining HSI models for selected species. Then the HMEM program provides the user with a list of existing HSI models and management activities from which selections can be made.

The Baseline or without management condition must be input and generally consists of a data set (from field evaluations) containing a value for each of the independent variables from the selected HSI models, plus values for the area of each of the surface cover types. The needed information is readily available upon completion of a HEP analysis. The user must next enter cost data so that the unit of costs of the management activities can be properly computed. Also, management goals must be specified in terms of habitat units (a separate goal can be established for each species). The selection is not left entirely to trial-and-error since HMEM provides some guidance by ranking management measures in order of their cost-effectiveness. The activity at the top of the rank order list produces the largest number of habitat units per dollar of management.

The top ranked activity would logically be selected for inclusion in the plan. However, there does remain the question of how many units of that activity should be included. HMEM performs a marginal cost analysis for each activity which generally, though not always, is logarithmic in shape. The idea is to select an amount of the management activity up to the point where the slope of the curve levels off rapidly. Following the selection of the number of units of the top-ranked activity to implement, HMEM calculates the total cost and the fraction of the goals achieved. This process is then repeated for the next-highest ranked management activity, and the selected number of units combined with those from the highest-ranked activity. HMEM again calculates the total cost of the plan at that stage, the habitat units mitigated and the fraction of the goal achieved. The process is continued until the combination of activities either meets or exceeds the specified management goals.

The result is the design of several different feasible plans by trying different combinations of management activities. These alternatives will be different both in total cost and relative contribution to individual habitat unit goals. These differences serve as the basis for the selection of plans for further study, presentation to the decision-maker, and possible implementation. HMEM was designed for micro-computers or PCs which support MS-DOS 3.0, and have an RM/FORTRAN compiler and the MICRO-HSI program software. In addition, the program

requires 512K bytes of random access memory, an 8087 math co-processor, one floppy disk drive, and a hard disk with a minimum of 10 megabytes of storage.

HMEM has been used by the Bureau of Reclamation on at least three projects and it is also planned to be used on the Tennessee-Tombigbee Waterway by the Mobile District of the Corps of Engineers. The following represent guidelines for the use of HMEM. (J. Hokenstrom, 1987. Habitat Management Evaluation Model - A User's Perspective, presented at the U. S. Army Corps of Engineers Seminar on Environmental Planning, 15-18 March, 1987.)

- Require the user to identify explicitly the habitat objectives that are to be addressed.

- Require the user to acknowledge the complexities involved in developing mitigation plans and provide him/her a systematic method to deal with them.

- Document the decision-making process followed in developing plan recommendations.

- Require the user to identify relationships between management actions and habitat response.

- Require the user to identify management costs by activity.

- Evaluate the effects of multiple increments of a single management action.

- Facilitate development of alternative management plans.

- Analyze cost-effectiveness of implementing a single unit of all management actions and provide a rank ordering of the actions.
- Allow users to compare the cost-effectiveness of alternative management plans.

- Result in the identification of areas where additional information is needed with regard to wildlife management.

Hokenstrom continues that HMEM will <u>not</u>:

- Make decisions for the user or optimize solutions;

- Consider all possible management options, only those the user programs into the system;

- Consider management actions that do not affect one or more HSI variables or area (e.g., people management);

- Define or identify specific limiting factors based on the HSI models;

- o Rank order combinations of management actions unless management action is defined as being composed of multiple actions;

- o Create new knowledge.

According to Hokenstrom, HMEM is applicable at both ends of the feasibility and design levels of planning. In addition, HMEM may also be useful in post-implementation monitoring studies. By developing the relationship between HSI and management actions, the monitoring can identify where responses did not reflect previous assumptions. The potential relationship can then be changed to reflect more accurately the observed conditions. Hokenstrom summarizes the positive and negative aspects of HMEM as follows:

- o The HMEM program allows the rapid development of cost-effective management plans;

- o HMEM is applicable to both general and site-specific planning studies although site-specific studies will probably be more complicated from the standpoint of computer code to cover unique situations;

- o The process of building management action models resulted in the identification of deficiencies in some HSI models and their subsequent modification. It was also evident that the complexity and precision of the management action models were much greater that of the HSI models. This meant that many potential management actions could not be used because the HSI models did not contain variables that would reflect responses to the actions. The team identified this aspect of the HSI models as a significant concern.

From the perspective of the Bureau of Reclamation, the major effort required to get HMEM ready for wide application to mitigation planning is to focus on developing HSI models that are sophisticated enough to reflect responses to a wide range of possible management activities. In addition, there is a need for developing an informative user's manual and additional testing of software. Although some effort has been initiated in these areas, there remains a significant amount of effort before HMEM can be ready for wide applications.

Based on this evaluation of HMEM, it appears that this program is the most promising of the existing methods for integrating environmental measurement and economic analysis of mitigation useful for incremental analysis. HMEM can at the very least produce better documented mitigation plans than the other techniques, and may represent an approach that with some further modifications and changes can be used by the COE for wide application to mitigation planning. In addition, further studies must be directed at modifying the HSI models to reflect responses to specific management actions. Also, there is a significant problem associated with the amount of subjective judgement left to the person operating the HMEM program. Efforts must be directed at identifying how subjective judgments can be highlighted for consideration by the decision-makers.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Current methods and procedures for mitigation planning do not provide an adequate basis for assuring the selection of a least-cost mitigation plan for COE projects.

The typical approach being taken by COE district planners is to develop a cost-effective plan for achieving 100% mitigation, as determined jointly by COE and FWS team members, and then to disaggregate the plan into separable increments to perform an incremental cost analysis as required by COE guidance under the P&G. The result for levels of mitigation less than 100% is not necessarily a cost-effective plan. Mitigation costs, particularly for a large project, could be significantly higher than necessary.

What is needed is a method for readily determining the least-cost combination of mitigation measures that comprise a mitigation plan for less than and up to and including 100% mitigation and for displaying these plans effectively to decision makers for selection of the level of mitigation appropriate for the project under consideration. The method developed should be consistent with basic economic concepts, including an approach based either on economic efficiency (benefit-cost analysis) or cost-effectiveness. Economic efficiency requires the assignment of monetary values to non-marketed goods, and most wildlife managers are unwilling to take this step. Therefore, the COE approach to mitigation planning relies on a cost-effectiveness framework. Other techniques developed for use in fish and wildlife evaluation include both linear (LP) programming and non-linear programming (NLP) for modeling biophysical responses of species with their habitats. However, the complexity of these approaches and the current lack of understanding of most species' biophysical responses to habitat changes have held up applications of LP or NLP models to all but a few selected projects. Therefore, a mechanism is still needed to assemble different habitat mitigation measures into separable, cost-effective plans that achieve various mitigation goals up to 100% mitigation to be displayed in the form of a cost/mitigation tradeoff curve for consideration by the decision maker.

At the heart of incremental mitigation planning is the ability to measure the characteristics of each habitat in quantifiable units. Four habitat measurement techniques have been investigated in some detail, HEP, PAM HEP, HES and WET to evaluate their applicability to incremental mitigation planning. It has been shown that HEP, PAM HEP, and HES but not WET are applicable to the type of incremental mitigation planning required by the most recent COE directives.

HEP is based on the selection of a few indicator species to characterize the entire habitat. Habitat suitability indices (HSI's) are calculated for each species for the without- and the with-project conditions. The product of the HSI's and the habitat acreage provide the number of habitat units (HU's) that must be considered in the mitigation plan for that species. The sum of the HU's for all of the species gives the total HU's for mitigation. If certain species are

considered more important or critical, a relative value index (RVI) is used to modify the results for the overall habitat.

PAM HEP is a method based on HEP but which has been simplified, including the use of fewer sampling points and generally fewer species to characterize the habitat than HEP. Generally also, the same HSI's are used for the same species.

HES is based on characterizing the entire habitat as a community of species. The habitat quality index (HQI) has been developed to date for a relatively few habitats. The HQI multiplied by the acreage of the habitat provides the habitat unit value (HUV) akin to the HU above.

WET is based on a qualitative assessment of a wetland in the without- and with-project condition. A series of questions are posed to the mitigation planner from which the project impacts are estimated. The mitigation plan is determined based on the lowest cost to achieve a specified level of mitigation. Since WET does not provide quantified measures of habitat characteristics, it is not appropriate for incremental mitigation planning.

It has been concluded that HEP is appropriate for use in mitigation planning where the most accuracy is desired and the necessary time and funds are available to conduct the full HEP analysis. Where funds and time are limited, PAM HEP is becoming more and more widely used. However, there is still some question as to the accuracy of PAM HEP in relation to HEP, given the lesser amounts of data used. HES is appropriate for use in the types of habitat for which it has been developed, currently the hardwood bottomlands of the lower Mississippi River basin.

To incorporate the quantified HU or HUV measurements into an economic framework, the use of the Habitat Management Evaluation Model (HMEM) appears to offer significant advantages over current approaches to biophysical response modeling or other optimization techniques. HMEM is an interactive, menu-driven computer program which assists mitigation planners and decision makers in developing incremental plans to meet mitigation goals. HMEM computes the effectiveness of specified habitat management measures in terms of dollars per habitat unit ($/HU), and guides the user in combining the most cost-effective activities into an overall plan through incremental cost analysis. It is not an optimization technique because it does not find the absolute minimum cost plan, but it does produce the required mitigation cost curves for each set of mitigation measures from which the decisionmaker can determine which set represents the appropriate level of mitigation. The lowest cost plan within the selected set is readily observed from the curve.

Computer techniques have been developed to assist in determining habitat characteristics with all four measurement techniques, HEP, PAM HEP, HES and WET. However, the most advanced of these computer applications appears to be with PAM HEP. For this reason, it appears that combining PAM HEP with HMEM could possibly provide the most readily-usable, user-friendly overall capability for conducting incremental cost analysis in mitigation planning. This is not to say that the use of HEP, HES or WET for habitat measurement or characterization in particular projects would not be appropriate in certain circumstances, particularly in those cases where the project team is well-versed in that technique. Also, this is not to say that biophysical modeling using LP, NLP or other approaches may not be useful. For typical projects where time

and funds are limited, the use of PAM HEP with HMEM could provide an effective technique for identifying the most cost-effective environmental mitigation plan.

NEXT STEPS

A workshop should be convened with representatives from the COE, FWS, BuREC and other agencies involved in developing approaches to mitigation planning to discuss the further development and use of HMEM. If the further development and use of HMEM proves that it is as useful in mitigation planning as the above evaluation would indicate, then its use throughout the COE districts should be strongly supported.

The HSI models which have not yet been validated by in-depth biological studies of a particular species should be completed as soon as possible. All uses of HEP and PAM HEP which rely on un-validated HSI's are suspect.

The HSI models must match the availability of management measures for mitigation so as not to constrain the HMEM procedure. All of the HSI models should be reviewed, starting with the validated HSI models, to determine if additional development is needed to match the potentially useful management measures available for those species under the most generally applicable conditions.

The question of the accuracy and reliability of PAM HEP versus HEP should be resolved by conducting a careful comparison using both techniques applied to the same habitats.

PAM HEP has not specifically been used with HMEM, although presumably HMEM can use any set of quantified measures of habitat characteristics. Mitigation planning for one or more projects should be conducted using PAM HEP with HMEM and, if successful, an integrated user's manual, guidebook and software should be prepared for dissemination to the COE district planners. Training courses should be arranged on the use of PAM HEP/HMEM.

HEP and HES rely on much the same basic information, such as percent cover of various types, tree type and size, water quality, etc. The question of the validity of the species approach of HEP versus the community approach of HES might be resolved by further comparisons of the two techniques using both techniques applied to the same habitat. This comparison could be done using PAM HEP if the above comparison between HEP and PAM HEP shows the latter to be as accurate as the former. Also, this comparison could be done after HES has been extended to additional habitat types to allow a broader comparison to be made than is now possible.

The use of WET as a <u>preliminary technique</u> for mitigation planning of projects impacting wetlands, followed by the use of HEP, PAM HEP or HES, should be investigated as a means of rapidly identifying the critical features of the habitat to be mitigated. Although WET does not identify species for mitigation, nor focus on habitat-species relationships except for waterfowl, invertebrates and fish, it does provide a quick overview of potential project impacts which might be valuable in focusing a HEP, PAM HEP or HES analysis.

The discussion and evaluation of WET in Sections 3 and 4 was based on the documentation available from WET I and personal contact responses also based primarily on WET I. WET II

has been in development by the Waterways Experiment Station of the U. S. Army Corps of Engineers and the U. S. Department of Transportation for several years, and the documentation will be available imminently. The discussions and conclusions reached in Sections 3 and 4, and the above suggestion that WET might be used in conjunction with HEP, PAM HEP or HES, should be re-evaluated in the context of the WET II revisions.

Focus needs to be maintained on research to improve decision making by incorporating optimization methods. These methods include LP, the piece-wise LP approximations to NLP, NLP, and biophysical and bioeconomic models which can provide additional information to decision makers in determining the appropriate level of mitigation for each project.

APPENDIX A

EXAMPLES OF HABITAT MEASUREMENT TECHNIQUES

EXAMPLES OF HABITAT MEASUREMENT TECHNIQUES

EXAMPLE OF HEP APPLICATION

HEP has been widely used by the COE for measuring habitat both with and without project for mitigation planning. HEP was used to establish baseline habitat measurement for the Passaic River Basin study. Subsequent studies used this baseline data along with future land uses to identify habitat changes at different time intervals and measure both losses and gains that may result from the implementation of the proposed project.

The Passaic River Basin is located in northeastern New Jersey and southeastern New York and drains an area of approximately 935 square miles. Flooding is common throughout this region, and the purpose of this study was to develop a plan for water management and flood control. HEP was used to determine the baseline conditions so that the environmental impact of proposed projects could be evaluated and taken into consideration throughout the formulation of alternative plans.

A team approach was used during this HEP analysis consisting of two Fish and Wildlife Service biologists and a third biologist from the COE. The procedure used to select evaluation species involved categorizing the vertebrate species in the study area according to their feeding and reproductive guilds. Feeding guilds are defined in terms of feeding strategies (e.g., seed or insect eater, salliers or hawkers) and the strata locations where foods are obtained (e.g., canopy, shrub layer or ground level). Reproductive guilds are defined in terms of where reproduction occurs (e.g., tree cavities, ground nesters). This information is necessary to determine the Habitat Suitability Indices for each evaluation species. The availability of draft HSI models was the primary determinant for the selection of evaluation species (Table A-1).

HEP analysis requires the delineation of cover types. If the study is divided into relatively homogenous areas, the necessary sampling effort is reduced. The study team defined three areas based on the National Wetlands Inventory (NWI) map overlays. Within these areas, sample sites were selected for the field evaluation. Sample sites were selected based upon a restricted, stratified, randomized design using a dot grid. No more than five sites were sampled for each of the cover types, and the actual number allotted to each cover type was proportional to the aggregate areas of each cover type.

Field work for the HEP study was conducted between April 28 to June 5, 1980. When sample sites were not readily accessible by roads, trails or with the aid of landmarks, azimuths were determined, and the sites were located with the use of a Jacob staff, forester compass, fiberglass measuring tape and range poles. Once on site, notes on the plant species composition, vegetational community structure, and the signs of faunal species observed and/or heard were noted. Measurements of the variables that relate to each species were taken from a randomly cast, 200-ft. long line transect. This transect served as the primary sampling unit. For example, attributes such as percent forb, grass, shrub and overstory canopy cover were assessed by interception (i.e., the actual number of interceptions of a possible 200). When an interception occurred, the height(s) of the herb and/or shrub layer was/were measured. The heights and the diameter-at-breast height of the trees whose canopies were intercepted were measured with a

Table A-1: Guilds Used to Select Species in HEP--Feeding and Reproductive Guilds of Selected Evaluation Species for the Passaic River Basin Terrestrial HEP Study. Adapted from Noon, et al (1979) and Samson (1979).

	FEEDING GUILD															REPRODUCTIVE GUILD					COVER TYPE ASSOCIATIONS				
	PRIMARY FOODS					FORAGING SITE					FEEDING BEHAVIOR														
EVALUATION SPEICES	HERBIVORE (1)	HERBIVORE (2)	INSECTIVORE	OMNIVORE	CARNIVORE	GROUND (3)	GROUND (4)	LOW CANOPY	MIDDLE CANOPY	WATER	BROWSER	GRAZER	FORAGER	GLEANER	PREDATOR	WATER	GROUND	NEST SITE, LOW	NEST SITE, HIGH	CAVITY	PFO1	PSS1	PEM1 (5)	UR	UH
WF			X			X									X	X					X				
GH					X		X			X					X			X				X	X		X
GHO					X										X				X		X	X	X		X
RG	X	X					X	X			X		X				X								
R-WB		X											X					X			X	X	X		
B-CC			X						X					X				X		X				X	X
SS		X					X						X					X						X	
ECR	X						X					X					X				X			X	X
M	X									X		X					X					X	X		
GS					X		X						X							X				X	
R						X							X							X	X	X	X	X	X
W-TD	X							X			X						X				X	X	X		X

WF = wood frog; GH = green heron; GHO = great horned owl;; RG = ruffed grouse
R-WB = red-winged blackbird; B-CC = black-capped chickadee; SS = song sparrow;
ECR = eastern cottontail rabbit; M = muskrat; GS = gray squirrel; R = raccoon
W-TD = white-tailed deer

(1) Herbivore - leaves, stems, twigs; (2) Herbivore - fruits, seeds, buds; (3) ground-marshy or wet
(4) ground-moist to dry; (PEM was not assesed in the Upper Passaic Study Area

Biltmore stick. However, when deemed necessary or prudent by the study team, supplemental estimates or measurements were made.

The number of habitat units (HU's) associated with an evaluation species in a given study area is related to both habitat quality (i.e., HSI) and the amount of available habitat (i.e., HA). The relationship is multiplicative (i.e., HSI x HA = HU). The baseline HU's for each of the twelve evaluation species based on this field analysis is presented in Tables A-2, A-39 and A-4.

The HEP is used to evaluate mitigation plans in the following manner. If it is assumed that the total surface area of a study area is a constant but that the proportion of each cover type within the same study area is alterable, then to maintain a specified number of HU's within the area to offset project losses requires that:

1. HSI's of some species be increased to offset decreased HSI's associated with other species; or,

2. HA's of some species be increased to offset decreased HA's associated with other species; or,

3. Both HSI's and HA's associated with several species be increased to offset decreased HSI's and/or HA's associated with other species.

Therefore, any desired corrective action, depending upon the unique aspects of the situation and the management objectives, could be accomplished by appropriately affecting either HSI or HA individually or in some combination. This is the basis for developing mitigation plans and is achieved by assembling a number of separate management measures to produce the number of HU's established as the mitigation goal.

Example of PAM HEP Application

PAM HEP has recently been used by the COE in formulating mitigation plans for the modification of the Francis E. Walter Reservoir located in northeastern Pennsylvania. This reservoir was built by the COE and became operational in 1961. It controls a predominantly forested 288 square mile drainage area.

In 1981, the COE began pre-construction planning for modifications to the reservoir to provide for increased water supply and recreational opportunities. In conjunction with the FWS, the PAM HEP measurement technique was used by the COE to evaluate the potential impact this project would have on wildlife resources. PAM HEP was selected because it evaluates a single set of future conditions, both with and without the project and is substantially less expensive to use than the HEP, which evaluates several sets of future conditions.

PAM HEP was used to evaluate the existing terrestrial habitats in terms of Habitat Units. This would allow changes associated with the implementation of the proposed project to be measured in quantitative terms. A team was formed made up of various personnel from the FWS, the Pennsylvania Game Commission (PGC), the Pennsylvania Fish Commission (PFC), and the COE to perform the habitat evaluation. The following steps were performed by the team

Table A-2: HEP Form B for Study Area III

(HEP Form B) Habitat Units in Study Area III, Upper Wetlands, for Proposed Action and Target Year

1. Study : PRB - Study Area III, Upper Wetlands				
2. Proposed Actions:		3. Target Year: Baseline		
4. Evaluation Species	5. Area of Available Habitat in Acres	6. Habitat Suitability Index	7. Habitat Units (HA) x (HSI) = HU	
	(HA)	(HSI)	(HU)	(%)
WF	1359	0.5	680	5
GH	403	0.4	161	1
GHO	1967	0.8	1574	11
RG	205	0.4	82	<1
R-WB	1762	0.4	705	5
B-CC	4051	0.4	1620	12
SS	3846	0.5	1923	14
ECR	5410	0.4	2164	16
M	403	0.2	81	<1
GS	3846	0.2	769	5
R	5813	0.5	2907	21
W-TD	1967	0.6	1180	9
		8. Total	13846	100

Evaluation Species: WF = wood frog; GH = green heron; GHO = great horned owl; RG = ruffed grouse; R-WB = red-winged blackbird; B-CC = black-capped chickadee; SS = song sparrow; ECR = eastern cottontail rabbit; M = muskrat; GS = gray squirrel; R = raccoon; W-TD = white-tailed deer

Table A-3: HEP Form B for Study Area IV

(HEP Form B) Habitat Units in Study Area IV, Central Wetlands, for Proposed Action and Target Year

1. Study : PRB - Study Area IV, Central Wetlands				
2. Proposed Actions:		3. Target Year: Baseline		
4. Evaluation Species	5. Area of Available Habitat in Acres (HA)	6. Habitat Suitability Index (HSI)	7. Habitat Units (HA) x (HSI) = HU (HU)	(%)
WF	9044	0.5	4522	6
GH	3931	0.5	1966	3
GHO	14000	0.9	12600	19
RG	1025	0.2	205	<1
R-WB	12975	0.5	6488	10
B-CC	9896	0.5	4948	7
SS	8871	0.3	2661	4
ECR	18940	0.4	7576	11
M	3931	0.4	1572	2
GS	8871	0.3	2661	4
R	22871	0.5	11436	17
W-TD	14000	0.8	11200	17
		8. Total	67835	100

Evaluation Species: WF = wood frog; GH = green heron; GHO = great horned owl; RG = ruffed grouse; R-WB = red-winged blackbird; B-CC = black-capped chickadee; SS = song sparrow; ECR = eastern cottontail rabbit; M = muskrat; GS = gray squirrel; R = raccoon; W-TD = white-tailed deer

Table A-4: HEP Form B for Study Area V

(HEP Form B) Habitat Units in Study Area V, Upper Passaic, for Proposed Action and Target Year

1. Study : PRB - Study Area V, Upper Passaic				
2. Proposed Actions:		3. Target Year: Baseline		
4. Evaluation Species	5. Area of Available Habitat in Acres (HA)	6. Habitat Suitability Index (HSI)	7. Habitat Units (HA) x (HSI) = HU (HU)	(%)
WF	1393	0.5	697	4
GH	342	0.3	103	1
GHO	1735	0.7	1215	8
R-WB	1735	0.6	1041	6
B-CC	2605	0.6	1563	10
SS	2605	0.7	1824	11
ECR	3998	0.5	1999	12
M	342	0.2	68	<1
GS	2605	0.6	1563	10
R	4340	1.0	4340	27
W-TD	1735	1.0	1735	11
		8. Total	16148	100

Evaluation Species: WF = wood frog; GH = green heron; GHO = great horned owl; RG = ruffed grouse; R-WB = red-winged blackbird; B-CC = black-capped chickadee; SS = song sparrow; ECR = eastern cottontail rabbit; M = muskrat; GS = gray squirrel; R = raccoon; W-TD = white-tailed deer

prior to the required fieldwork and data collection:

PAM HEP ANALYSIS STEPS:

1. Definition of study areas
2. Delineation and categorization of land use/cover types
3. Identification of critical and unique habitats
4. Selection of evaluation species
5. Development of species models
6. Selection of sample sites.

After the sample sites were selected by the team, the Habitat Suitability Indices were determined based on field investigations. The procedure that was used involved the confirmation of land use/cover types and then selection of a sample size for detailed evaluation, which varied from less than an acre to over 50 acres, depending on visibility, accessibility, and time spent on site. By common agreement, the FWS representative recorded all data and each team member evaluated each species life requisite separately. The FWS representative randomly solicited the ratings of team members for each life requisite to avoid any bias in the evaluation. Team members justified their ratings based on parameters identified in the species models. After solicitation of ratings for each life requisite from all members of the team, the results were averaged, and the lowest average was selected as the habitat suitability index (HSI). In cases where a particular life requisite was absent or very low on site, the team evaluated that requisite offsite in a nearby land use/cover type as required by the PAM HEP Manual. This procedure was followed for each species per sample site. The HSI's from all of the sample sites were then used to calculate "mean Habitat Suitability Indices." The mean HSI's for each species was then multiplied by the baseline area to calculate the Habitat Units for each of the selected land use/cover types. These were then added together totaling 13,648 Habitat Units for the study area prior to the construction of the proposed project.

After the number of existing Habitat Units was determined, efforts were directed towards calculating the Habitat Units that would exist after the proposed modification was built. The basic concept was to compare the number of existing Habitat Units against those that would exist after the project was implemented. Differences resulting from the comparison constitute the impacts of the project and are used to determine the mitigation goals and the extent of mitigation required.

In order to undertake the comparison, detailed planning information about the proposed modifications was required. Since the COE was the project sponsor, they provided the information needed to calculate the Habitat Units that would exist after project implementation. Area calculations of with-project land use/cover types were conducted using the Numonics Calculator. This procedure was repeated for each of the land use/cover types used in the calculation of existing habitat. Determination of with-project Habitat Units was accomplished by multiplying with project land use/cover type acreages by the HSI's that were generated during the baseline assessment. This procedure was repeated for all species within each land use/cover type. The Habitat Units were then summed and compared with the baseline Units (in Table A-5). The results show that the implementation of the proposed project would result in a net loss of 1,924 Habitat Units. Over all, ten evaluation species declined in Habitat Units, while five

TABLE A-5

PAM HEP Form 8

PENNSYLVANIA MODIFIED 1980 HEP - COMPARISON ANALYSIS OF HU CHANGES FROM BASELINE (TY0) TO CONSTRUCTION (TY1) FOR EVALUATION SPECIES

Project Francis Walter (Modified Date

Alternative Permanent Pool 1427' Flood Pool 1482'

Evaluation Species	TY0 HU	TY1 HU	Change Amt.	Change %
Deer				
Herbacious Rangeland	7.8	5.5	-2.3	
S&B Rangeland	76.4	94.9	18.5	
Dec. Forest	1915.6	1675.2	-240.4	
Mx. Forest	124.1	111.7	-12.4	
Palustrine S/S Wetland	6.4	6.4	0.0	
Palustrine Forested Wetland	91.8	90.6	-1.2	
Transition	389.9	100.7	-289.2	
Total	2,612.0	2,035.0	-527.0	
Raccoon				
Herbaceous Rangeland	13.6	9.7	-3.9	
S&B Rangeland	63.7	79.1	+15.4	
Dec. Forest	2,394.0	2,094.0	-300.0	
Mx. Forest	173.7	156.4	-17.3	
Palustrine Pond Wetland	7.3	6.8	-0.5	
Palustrine S/S Wetland	8.1	8.1	0.0	
Palustrine Forest Wetland	153.0	151.0	-2.0	
Lacustrine Littoral Wetland	3.0	22.5	+19.5	
Riverine Wetland (Forest Border)	94.4	63.4	-31.0	
Riverine Wetland (Transition Border)	49.2	0.0	-49.2	
Transition	315.1	80.6	-234.5	
Total	3,275.1	2,671.6	-603.5	
Ruffed Grouse				
Herbaceous Rangeland	1.9	1.4	-0.5	
S&B Rangeland	50.1	63.2	+13.1	
Total	52.0	64.6	+12.6	
Woodcock				
Herbaceous Rangeland	3.9	2.7	-1.2	
Palustrine S/S Wetland	6.4	6.4	0.0	
Total	10.3	9.1	-1.2	
Project Area Totals				

TABLE A-5 (continued)

PAM HEP Form 8

PENNSYLVANIA MODIFIED 1980 HEP - COMPARISON ANALYSIS OF HU CHANGES FROM BASELINE (TY0) TO CONSTRUCTION (TY1) FOR EVALUATION SPECIES

Project Francis Walter (Modified Date

Alternative Permanent Pool 1427' Flood Pool 1482'

Evaluation Species	TY0 HU	TY1 HU	Change Amt.	Change %
Rattlesnake				
S&B Rangeland	89.2	110.7	21.5	
Transition	236.3	60.4	-175.9	
Total	325.5	171.1	-154.4	
Coopers hawk				
Dec. Forest	3,352.3	2,931.5	-420.8	
Mixed Forest	173.7	156.4	-17.3	
Total	3,526.0	3,087.9	-438.1	
Hairy woodpecker				
Dec. Forest	2,873.4	2,512.7	-360.7	
Mixed Forest	198.5	178.7	-19.8	
Total	3,071.9	2,691.4	-380.5	
Wood frog				
Palustrine Pond Wetland	4.4	4.1	-0.3	
Palustrine S/S Wetland	9.7	9.7	0.0	
Palustrine Forested Wetland	76.5	75.5	-1.0	
Riverine Wetland (Forest Border)	53.9	36.2	-17.7	
Total	144.5	125.5	-19.0	
Wood duck				
Palustrine Pond Wetland	11.7	10.9	-0.8	
Lacustrine Limnetic	7	125.8	118.8	
Lacustrine Littoral	1	7.5	6.5	
Total	19.7	144.2	124.5	
Green heron				
Palustrine Pond Wetland	4.4	4.1	-0.3	
Riverine Wetland (Transition Border)	19.7	0	-19.7	
Total	24.1	4.1	-20.0	
Snowshoe hare				
Palustrine Forested Wetland	137.7	135.9	-1.8	
Total	137.7	135.9	-1.8	
Project Area Totals				

TABLE A-5 (continued)

PAM HEP Form 8

PENNSYLVANIA MODIFIED 1980 HEP - COMPARISON ANALYSIS OF HU CHANGES FROM BASELINE (TY0) TO CONSTRUCTION (TY1) FOR EVALUATION SPECIES

Project Francis Walter (Modified Date

Alternative Permanent Pool 1427' Flood Pool 1482'

Evaluation Species	TY0 HU	TY1 HU	Change Amt.	%
Beaver				
Lacustrine Littoral	1.0	7.5	+6.5	
Riverine Wetland (Forest Border)	94.4	63.4	-31.0	
Riverine Wetland (Transition Border)	9.8	0	-9.8	
Total	105.2	70.9	-34.3	
Kingfisher				
Lacustrine limnetic	14	251.6	237.6	
Lacustrine littoral	1	7.5	6.5	
Riverine Wetland (Forest Border)	27	18.1	-8.9	
Riverine Wetland (Transition Border)	29.5	0	-29.5	
Transition	236.3	60.4	-175.9	
Total	307.8	337.6	29.8	
Canada Goose				
Lacustrine Limnetic	28	125.8	97.8	
Total	28.0	125.8	97.8	
Coot				
Lacustrine Limnetic	0	0	0	
Total	0	0	0	
Project Area Totals	13648	11724	1924	

increased. The team met to review the baseline and impact assessment results and to consider appropriate mitigation measures. Possible mitigation measures that were evaluated included:

1. Construction of sub-impoundments at the upper ends of several embayments.
2. Installation of one thousand wood duck nesting boxes.
3. Creation of strips of herbaceous vegetation along the shoreline.

These and other available measures were considered, and eventually a mitigation plan was recommended which included the construction of a pond, installation of nesting boxes, various plantings, and clearing of deciduous forestland which limits HSI values. These measures raised the HSI values enough so that the Habitat Unit losses associated with the project were canceled by the Habitat Unit gains associated with these mitigation measures. From this evaluation, it can be concluded that the PAM HEP is a valid approach to habitat evaluation which can be used in mitigation planning. Although it is not as comprehensive as the HEP in its application and biological models, it has earned the respect of most of those familiar with it as a legitimate modification of the HEP. It is particularly suitable for small projects with limited budgets which are not likely to affect endangered or valuable wildlife resources.

Example of HES Application

The HES technique was used by the New Orleans District to evaluate the habitat losses that could be brought about by the construction of hurricane surge protection measures along the Mississippi River near New Orleans. Field tests were performed to determine the following average HQI's for key biological communities/habitats--Bottomland Hardwoods (BLH) .79 (13 samples), wooded swamp (WS) .69 (17 samples), drained wooded swamp (WSD) .63 (8 samples). Marsh was assumed to be 1.0 since no model exists for marsh and acreages involved were minor. By applying the HQI score to the acres of habitat type at predetermined points in time over the life of a project for the with- and without- project conditions, changes in habitat quality, because of the project, can be measured in terms of average annual Habitat Units (AAHU's). Table A-6 shows the losses in Habitat Unit quantities associated with four alternatives ranging from 408.45 to 542.51 AAHU's. These losses in 17 land use categories provided the basis for determining mitigation plans and goals.

After the HES analysis was performed and habitat losses documented, the COE investigated the feasibility of several mitigation options in conjunction with the FWS, Louisiana Department of Wildlife and Fisheries (LDWF), and the National Park Service (NPS). The goal set by these agencies was for 100 percent mitigation of bo' nland hardwood, marsh, and undrained wooded swamp habitat in-kind. (This goal is consistent with the FWS Mitigation Policy (1981) which designates these as Category 2 Resources which demands "no loss of in-kind habitat value" because they are relatively scarce and unique). Several mitigation plans were developed but most were eventually determined to be impractical due to high cost, relatively low benefits, or for other reasons. The following, however, were considered in detail:

Plan A: Acquisition of 62 acres of bottomland to mitigate all BLH losses.

Plan B: Acquisition of 1,097 acres of undrained wooded swamp to mitigate all WS losses.

Table A-6: Project Impact Analysis of Average Annual Habitat Units (AAHU's) by Alternative (according to HES)

Alternative	Land Use*	Future: With Project	Future: Without Project	Changes in Habitat Units
V-South SPH	WSD	352.37	445.54	-93.17
	BLHD	30.26	40.53	-10.27
	MARSHD	279.17	340.20	-61.03
	WS	8.44	337.41	-328.97
	BLH	2.51	23.31	-20.80
	MARSH	0.72	29.00	-28.28
V-North SPH	WSD	337.35	445.54	-108.19
	BLHD	30.14	40.53	-10.39
	MARSHD	279.17	340.20	-61.03
	WS	46.11	337.41	-291.30
	BLH	7.13	23.31	-16.18
	MARSH	29.00	29.00	0
MD-SPH	WSD	334.75	445.54	-110.79
	BLHD	30.14	40.53	-10.39
	MARSHD	273.93	340.20	-66.27
	WS	46.11	337.41	-291.30
	BLH	7.13	23.31	-16.18
	MARSH	29.00	29.00	0
MD-100	WSD	353.99	445.54	-91.55
	BLHD	30.62	40.53	-9.91
	MARSHD	275.43	340.20	-64.77
	WS	111.37	337.41	-226.04
	BLH	7.13	23.31	-16.18
	MARSH	29.00	29.00	0

*Land uses are WS = wooded swamp, BLH = bottomland hardwoods, and MARSH. Habitats followed by the letter D indicate that the area is subject to forced drainage.

Plan C: Combinations of Plan A and Plan B to fully mitigate all BLH and WS.

Plan D: Acquisition of 1,407 acres of wooded swamp to mitigate all WS and WSD and acquisition of 62 acres of bottomland hardwood to mitigate all BLH losses.

Plan E: Acquisition of 62 acres of BLH and acquisition of 1,610 acres of WS to mitigate all project-caused losses except for marsh habitats.

The recommended mitigation plan involved the construction of a stone dike at the mouth of Baie du Cabanage (a large swampy marsh) and the acquisition of approximately 1,160 acres of wooded wetlands to include a minimum of 62 acres of bottomland hardwoods (Plan E). The recommended plan would fully compensate all significant wildlife losses associated with any of the proposed hurricane-surge-protection alternatives and represents the most cost-effective combination of measures available. Figure A-1 shows the cost associated with implementing these mitigation measures and the AAHU's compensated by them.

The future of HES and its ability for universal application remains uncertain and depends on the interest in creating biologic models for additional habitat types outside of the Lower Mississippi Valley. Nevertheless, HES is regarded as an approach with substantial biological validity that is less costly and time consuming than HEP and more widely recognized than PAM HEP or WET.

Example of WET Application

An example of a WET analysis has been provided for a highway project in Aberdeen, Washington which was proposed to cross a stream using a culverted fill, "A Method for Wetland Functional Assessment, Vol. I," U.S. DOT, FHA, ORD, Washington, D.C., Report No. FHWA-IP-82-23, March 1983, pp 168-176. The stream flows down a steep gradient through a forested area into a narrow, shallow but permanently flooded arm of a river. Two wetland impact areas were identified, the actual stream crossing above the flooded arm, and the wetland surrounding the flooded arm where the stream met the river. The results from the Form C's indicated high potential impacts. Seven modified plans were identified. Two of these plans were eliminated based on potentially high impacts remaining for some of the functions. The recommended plan was selected from among the remaining five modified plans based on its capability to achieve essentially full mitigation for no cost increase over achieving intermediate mitigation.

This study was able to locate only a few other examples of the WET used to evaluate impacts to habitat and mitigation planning. Partly this is because WET has recently been revised, and it has not yet been tested in the field. Another reason is that many planners feel that this approach is useful as a preliminary tool to determine the overall impacts, but that it falls short of comprehensively evaluating these mitigation needs.

Unlike the preceding discussions of HEP, PAM HEP, and HES, a case study example of the use of WET in COE mitigation projects is not included. Two examples of the use of WET in COE projects were cited; however, in neither of these projects was WET used to develop mitigation plans. One example involved the Charleston District COE approval of a wetlands site for the private development of a shopping center. WET was used in this application as a

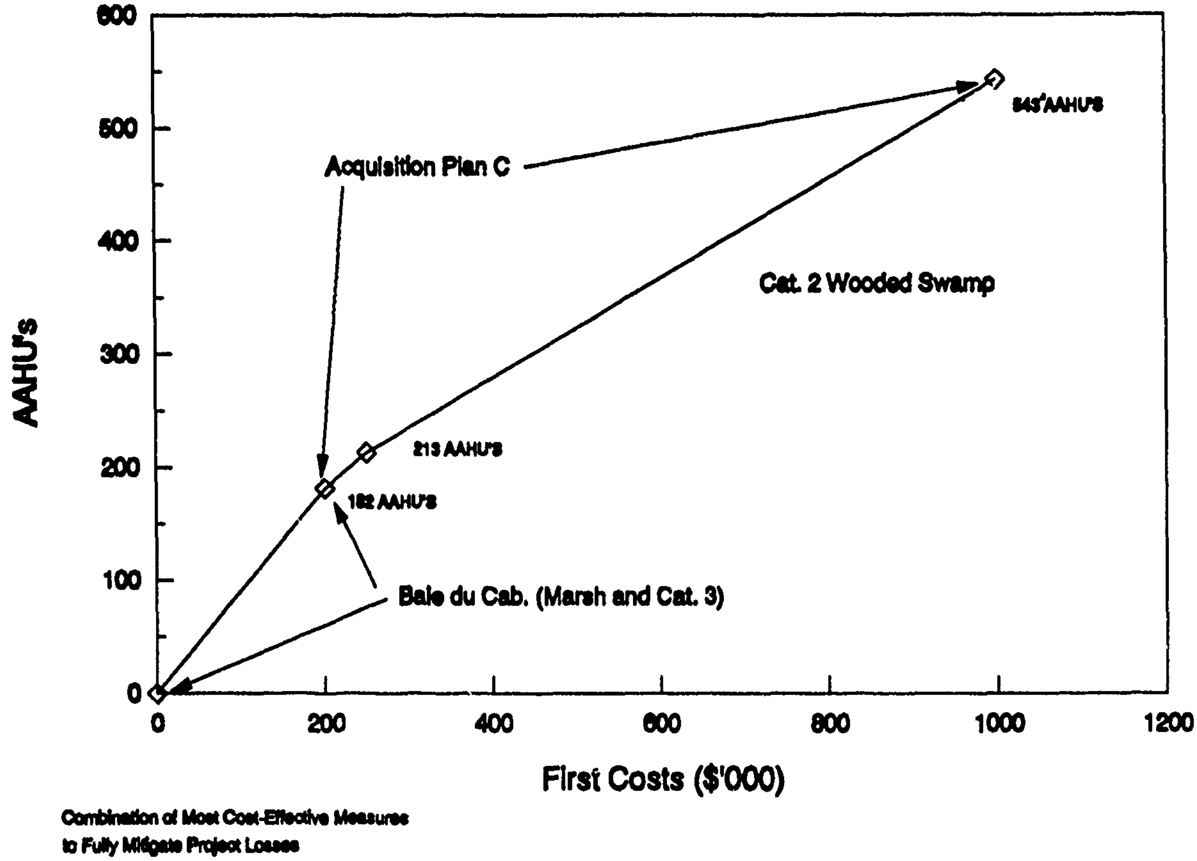

Figure A-1: HES Cost-Effectiveness Chart

preliminary tool in defining the project-induced impacts to the wetland habitat. A HEP analysis was then conducted to specifically address impacts to the fish and wildlife habitat and mitigation planning and analysis.

WET was also used in a similar capacity for a feasibility study by the Omaha District COE. This study was for the Two Forks Dam project, a water supply reservoir for the City of Denver. WET was used to provide background information for mitigation planning.

WET fills a significant role in the areas of wetland evaluation. In situations involving resources other than fish and wildlife, it is currently the most precise evaluation tool available to planners. When fish and wildlife resources are involved, however, it lacks the biologic validity and accuracy of the other methods being evaluated. But, in instances when it is necessary for precision to be compromised in order to achieve a quick overview assessment of mitigation needs in a wetland environment, the WET can be extremely useful. When under tight time and budget constraints, as is often the case in regulatory proceedings for private development, the WET can be effectively implemented.

APPENDIX B

PROFESSIONALS CONTACTED

CONTACTS

U.S. ARMY CORPS OF ENGINEERS

John Belshe, Chief of Environmental Resources, Office of Chief Engineer:

Mr. Belshe oversees all of the work being done on mitigation and impact measurement techniques being done by all of the COE researchers in various labs. He emphasizes the importance of the COE in maintaining a credible knowledge base from which to technically review any new or refined model for mitigation. The need for this knowledge base justifies the COE's extensive research effort in the area of mitigation.

David Castanon (Los Angeles District, COE):

Mr. Castanon has worked extensively with HEP in conjunction with incremental analysis on mitigation planning for projects, including the Nugales Wash and Upper Santa Ana flood control feasibility efforts. He feels that HEP is a useful tool and can be used successfully in the development of alternative mitigation plans.

Ellis Clairain, Waterways Experiment Station (WES):

Mr. Clairain's work at WES involves further development of the Wetlands Evaluation Technique (WET-II) originally developed by FHWA. WET-II addresses a multiple of wetland functions, including groundwater recharge and discharge, sediment trapping, nutrient retention, active recreation, uniqueness in heritage, and fish and wildlife habitat. WET-II was designed to give planners a broad overview of project impacts to these functions, as well as a quick approach to determine the approximate extent of necessary mitigation requirements. In contrast, the HEP model, designed by the Fish and Wildlife Service, focuses on fish and wildlife habitat. Although HEP requires more time, manhours, and funding to run, it is definitely more precise in the area of fish and wildlife than is WET-II. In the area of economic analysis and the WET-II model, Mr. Clairain explained that research is just beginning, and it is expected to take several years before any substantial integration of results are available.

Douglas Clark, Waterways Experment Station (WES):

Mr. Clark (Coastal Energy Group) is part of the team involved with further development of the Benthic Resources Assessment Technique (BRAT). Although, to his knowledge, this technique has not yet been linked to mitigation efforts, it is a method used for habitat evaluation and impact analysis. BRAT is a method which links fish food habitat data with benthic data and analyzes the change in function of a habitat as a whole. One assumption used in this method is that the fish food resources, generally found towards

the surface of the water, are of more value than the larger, deep body organisms. The BRAT approach has been applied in studies in the Chesapeake Bay and Puget Sound by the Waterways Experiment Station.

Randall Devendorf (St. Paul District, COE):

Mr. Devendorf's experience with habitat evaluation techniques is primarily with the HEP procedure used predominantly in the St. Paul District. Mr. Devendorf co-authored a paper outlining the experiences of the St. Paul office with HEP and incremental analysis.

Michael Eubanks (Mobile District, COE):

Mr. Eubanks was contacted regarding the use of the Man-Day/Monetary Evaluation Procedure (MEP) and the Traditional Evaluation Procedure (TEP) in the Tennessee-Tombigbee Waterway Wildlife Mitigation Feasibility Study. He said that both methods were used as supplementary methods to HEP, as was required by regulations. Neither of these approaches are currently in use.

John Forren (Philadelphia District, COE):

John Forren was formerly a biologist at the Philadelphia District Office of the COE. PAM HEP is the primary technique of habitat evaluation used in this office, and it has received varying degrees of acceptance throughout the field. This office works in close cooperation with other agencies within their region in devising acceptable mitigation plans.

Michael Gilbert (Omaha District, COE):

Mr. Gilbert has used WET in mitigation planning. He feels the technique is useful but needs refinement.

Donald Hershfeld (Huntington District, COE):

Mr. Hershfeld played a major role in the development of the Energy Flow Model (EFM) while at Virginia Polytechnic Institute and State University (VPI & SU), and continues in refinement of this model in his position with the Huntington District of the COE. As is the case with all of the techniques being developed to measure impacts to fish and wildlife, EFM performs most nearly to its potential when used for specific situations. EFM is a trophic model and is able to estimate direct and indirect impacts to feeding habitat. It is a tool for clearly defining the changes in the trophic aspects of a habitat. The best use of EFM would be for navigation project impacts, not only because this is what its best designed to do, but also because other models fall short of accurately measuring impacts to a habitat from navigational uses. EFM remains a model difficult

to implement because of its time demands. Data collection efforts should continue for a year in order to make the findings accurate.

Donald Hill (Charleston District, COE):

Mr. Hill feels that HEP is compatible with accepted procedures and ecological principals. Regarding WET, Mr. Hill feels that economic principles are not considered, however, the model is based on fundamental ecological principles but conceptually, not as precise as HEP.

Thomas Holland (Lower Mississippi Valley Division, COE):

Mr. Holland was one of the original developers of the Habitat Evaluation System (HES) in 1973. He has seen it go through several revisions, including one in 1980 and the most recent in 1988 by the Ecological Services Division of the State of Tennessee Department of Conservation. HES was developed based on two assumptions, (1) That an area could be divided into habitat types, and (2) that functional curves could be developed to represent the habitat. The major criticism of the originial HES model was that it lacked documentation necessary to gain confidence in the functional curves (a criticism which has been addressed and corrected in subsequent revisions and expansions of the model). Mr. Holland notes that the major difference between HES and HEP is in their orientation. HEP is a species directed model and HES is more community habitat oriented. Another difference is the time demand required to use the models. HEP requires a team of individuals and a varying length of time The amount of time needed to implement HES varies depending on the nature and extent of the study area being evaluated. A HES evaluation can be conducted in less time than a properly done HEP evaluation.

Richard Macomber, Board of Engineers for Rivers and Harbors, COE:

Since 1974 when habitat-based evaluation was first being developed and implemented, he has observed this arena grow from an untried system lacking all confidence, to an evaluation approach which can fairly accurately evaluate losses to habitat. The key to a successful evaluation lies with the actual implementation--the expertise and responsibility of the individual using the model. This analysis is true for almost all of the methods he is aware of in use; HEP, WET-II, acre-for-acre replacement, and BRAT, to name a few. He also notes the selection of models is dictated more by a specific situation than the quality of the model as they all have a niche in which it performs better. The problems in mitigation come not from the basic habitat evaluation, but from the mitigation plan. Here, policies differ between departments and politics also come into play. So, although all may agree on the habitat evaluation, it may be years before a mitigation plan is agreed upon.

Jean O'Neill, Waterways Experiment Station (WES):

Ms. O'Neill is actively involved with the verification process of the Habitat Suitability Indices (HSI) used as the measurement technique in the Habitat Evaluation Procedure (HEP). The models are being validated based on the criteria used to develop them, which varies according to the species and the person who developed it. Criteria, such as species diversity, replaceability, and uniqueness are considerations in this process.

Thomas H. Roberts, Waterways Experiment Station (WES):

Dr. Roberts' work at WES involves reviewing and developing procedures which will best assist planners in arriving at sound habitat evaluations and mitigation plans. He has worked with several methods, including HEP, PAM HEP, and WET.

Michael Sheehan (New England Division, COE):

The New England District of the COE, under the supervision of Mr. Sheehan, has contracted with WES to do a 5-year pilot study on the use of the WET model. Based on the CEQ objectives and standards, the study will take a case-by-case approach for each permit application. Mr. Sheehan remains cautiously optimistic about the practicality of the WET model, although he anticipates limited application to the permit process in its current format.

Robert Soots, Board of Engineers for Rivers and Harbors, COE:

Mr. Soots is involved with reviews of project recommendations. Mitigation techniques and plans are included in this review. The majority of reports have utilized the HEP technique; a few from the Lower Mississippi Valley District use the HES approach. He feels that HEP and HES are both adequate models as long as they are implemented properly and objectively. When both have been applied to the same project, the results have been very close, with only an insignificant difference in acreage requirements.

U.S. ENVIRONMENTAL PROTECTION AGENCY

Mary Kentula, Environmental Research Lab-Corvalis, OR.:

Ms. Kentula is a member of a research team currently studying the success of created wetlands to mitigate losses. The research focuses on specific systems and the features of design. The project is in a working phase, and no conclusions are yet available.

Kathy Kunz, EPA Region 10:

Ms. Kunz has been involved with assessing resources for many years. Her experience includes a knowledge of HEP and WET, both of which have major limitations. Although these models are used to draw out useful data which may otherwise be overlooked, she recognizes that good professional judgement is the key to the process of measuring impacts to habitat. Mitigation planning comes down to negotiation between the parties involved.

U.S. DEPARTMENT OF THE INTERIOR

Frank Deluise, Branch of Federal Activities:

Mr. Deluise's position involves the review of 404 permits, including the aspect of mitigation. Because of the uncertainty regarding the ability of mitigation plans to meet the objectives of the plan, DOI has requested their National Ecological Research Center to attempt to address this question. The first step has been to develop a database of projects with a follow-up to the mitigation plans.

Gary Hickman, Office of Research, Fish and Wildlife Service:

Mr. Hickman emphasized the importance of the working relationship between the COE and FWS. When an investigation and study into mitigation measures is properly coordinated, there are generally fewer incidents of dissatisfaction with the selected plan. Mr. Hickman, being a major contributor to the development of the HEP model, is a proponent for its use. He feels that, while it still has a lot of room for refinement, it is at this point the most sophisticated and accurate approach for determining mitigation needs. Recent updates to the HEP model include the Habitat Management Evaluation Model (HMEM) and the Human Use and Economic Evaluation (HUEE) approach. Other systems being developed in the area of habitat valuation and measurement, such as the Habitat Evaluation System (HES) and the Wetlands Evaluation Technique (WET-II) are progressing at a slower pace. Although WET-II does take into consideration more habitats than HEP (limited to fish and wildlife), HEP remains the most comprehensive and accepted model for the measurement of impacts to fish and wildlife.

Lee Isingsher, National Ecology Research Center, Fish and Wildlife Service:

Mr. Isingsher has used HMEM in conjunction with an incremental analysis. He feels that both HEP and HES are good approaches to habitat measurement and indicated that WET was technically limited, not based on economic concepts and biased towards social values.

Forest Littrell, Paul Petty, and Terry Reed, Planning & Environment Staff, Bureau of Land Management:

The Bureau of Land Management (BLM) is responsible for managing timber, mining, and other such rights on public lands. Although the need for mitigation does arise, as described in planning documents provided by BLM staff, generally, the management of these lands excludes activity which would require compensatory mitigation. When the need for mitigation measures does occur, the HEP approach is generally applied. However, there is no standardized policy requiring HEP, since they feel a case specific approach to selecting appropriate methodology is more valuable. It was also emphasized by BLM staff that attempting to measure habitat in dollars and cents goes against good environmental policy and the temptation to do so should be avoided.

"Butch" Roelle, National Ecology Research Center, Fish and Wildlife Service:

Mr. Roelle explained the goals and objectives of the Research Center to be program development and support for field ecological offices. The Center has provided the field with tools to assist them with mitigation studies, such as a database of approximately 400 references dealing with mitigation.

Melvin Schaumberger, National Ecology Research Center, Fish and Wildlife Service:

Mr. Schaumberger discussed the importance of clearly defining assumptions while preparing a Resource Analysis Impact Assessment. When this is done and the HEP model is properly applied, the model provides an accurate evaluation of the impacts to resources due to a particular project. In cases when the HEP model is used to develop a management prescription for mitigation, HEP is not as accurate. Currently, individual HSI's are being devised and validated. As this is completed (perhaps 8-10 years), the HEP model will continually become more reliable.

William Taylor, Office of Program Analysis:

Mr. Taylor is an economist and the co-author of the Federal "Natural Resources Damages Regulations" which provide guidance on the valuation techniques used to measure damages to natural resources. The use of the "willingness to pay" principle is the basis of these procedures. Individuals implementing this principle to determine values must first decide the most appropriate method: travel cost, hedonic pricing, unit day values, factor income, or contingent valuation. Mr. Taylor discussed the difficulty in valuing the services derived from a wetland or other habitat area. It can be done, but only by valuing the use of the habitat to man.

Gary L. Williams, Office of Environmental Technical Services, Bureau of Reclamation:

Dr. Williams discussed a program to use concepts of cost-effectiveness in their planning decisions, which was developed as a practical method for managers. The system uses Habitat Units and Habitat Suitability Indices, developed for the Habitat Evaluation Procedure, in measuring effectiveness. This program is referred to as the Habitat Management Evaluation Model (HMEM) and was devised as a joint effort between the U.S. Bureau of Reclamation and the U.S. Fish and Wildlife Service. Dr. Williams provided a paper explaining this process, "A Microcomputer Program for Use in Designing Cost-Effective Habitat Management Plans," along with an example of implementation, "On-Farm Mitigation--An Alternative Approach to Mitigating Fish and Wildlife Impacts of Irrigation Development."

William Wylen, National Wetlands Inventory:

Mr. Wylen feels that the current state of research into mitigation is far from being able to confidently evaluate a habitat. And, the strides which have been made in research have not yet been made practical and understandable for the average field office user or independent contractor. Since successful implementation and execution are key elements to a model, and he has yet to see a model able to do this, he does not feel he can support any of the approaches currently being studied.

U.S. DEPARTMENT OF TRANSPORTATION

Charles Des Jardins and Fred Banks, Office of Environmental Policy, Federal Highway Administration:

Mr. Des Jardins and Mr. Banks provided a background into WET-II , the method of habitat evaluation developed by the Department of Transportation in conjunction with the Waterways Experiment Station. WET-II is an acronym for "Wetlands Evaluation Technique." Whereas, the HEP approach to evaluation is designed specifically to measure fish and wildlife habitat, that comprises only one aspect of the WET-II model, which is more universal in its approach. In addition to fish and wildlife, this model addresses flood plain habitat, marsh habitat, groundwater recharge and discharge, nutrient retention, plus a series of other functions. Coordination with other agencies with an interest in using and expanding this technique are underway, as many feel the WET-II model can fill in some voids left by HEP.

STATE AGENCIES

Daryl Durham, Department of Conservation, Ecological Services Division, State of Tennessee:

When Ms. Durham and her associates were looking for a model to assist in evaluating a specific habitat (the bottomland hardwoods) in Tennessee, they felt the Habitat Evaluation System (HES) would best fit their needs. The other considered model was the Habitat Evaluation Procedure (HEP), which was not selected primarily because it is more species-specific than HES. HES has more of a habitat community orientation. This would provide a broader evaluation on all communities, including plant and wildlife. Ms. Durham has continued to expand and revise the HES methodology since her early work with it. Most recently, she has expanded the model to accommodate factors such as tract size and watershed. This report was just released in August 1988 and is not yet available for general distribution.

Paul Hammel, Department of Conservation, State of Tennessee:

The Department of Conservation in the State of Tennessee chose the HES approach when seeking a habitat evaluation method to use in studying bottomlands. Their work with the model has brought a great deal more acceptance to the validity of the HES approach.

Hugh Palmer, Game Commission, Bureau of Wildlife Management, State of Pennsylvania:

Mr. Palmer has been involved with the Pennsylvania Modified Habitat Evaluation Procedure (PAM HEP) since the early 1980's, when the HEP Team in Pennsylvania began its development. Because HEP was time and budget demanding, a system was necessary to incorporate the theory behind HEP into a usable model. PAM HEP has modified HEP in the areas of accounting and procedure. It saves users 70 percent of the time necessary to use HEP. Although it has been criticized for being too shallow, it does give planners a good idea of impact measurement and mitigation needs.

UNIVERSITY AFFILIATIONS

James Gosselink, Center for Wetland Resources, Louisiana State University:

Although Mr. Gosselink is not directly involved with the field of mitigation or habitat impact measurement techniques, he does encourage a project-specific selection of the model to be used. Because all of the techniques depend on subjective judgement in the valuation process, it is necessary to use the model most effective in each particular case.

Dr. Francis Heliotis, Biology Department, George Mason University:

Dr. Heliotis and his team of graduate students are involved with a research project which may eventually lead to a broad range of applications. They are examining in detail a habitat area to assess and measure biological units. Although the objectives of this research were not clearly defined from the discussion with Dr. Heliotis, he does believe it could result in the development of a new system or approach to habitat evaluation.

Dr. Joseph Larson, Environmental Institute, University of Massachusetts:

Dr. Larson emphasizes the significant differences between the methodologies designed to evaluate and assess wetlands and those which are designed to actually quantify impacts for use in designing a mitigation plan. The first category utilizes these models as a planning tool and when designed, were not intended to be used to establish design criteria. The Wetlands Evaluation Technique (WET) is an example of a model established to specifically aid in identifying design criteria. Problems and confusion often arise when one tries to utilize a model for an application other than what it was designed to do.

Dr. Larson also mentioned the evaluation and assessment techniques developed and used by many state offices. Connecticut, Rhode Island, and New Jersey have methodologies designed specifically for their needs and used as planning tools to assist planners.

John Loomis, Division of Environmental Studies, University of California at Davis:

Dr. Loomis is actively involved with expanding the models being used to try to bridge the gap between biological measurement and economic valuation. The Human use and Economic Evaluation (HUEE) model utilizes the HEP approach to biologic measurement and applies the economic models of travel-cost and contingent value in an attempt to quantify the value of habitat resources. Mr. Loomis' current work is in the refinement of the economic models used in the HUEE procedure.

John Stoll, Department of Agricultural Economics, Texas A&M:

Mr. Stoll is involved with methods for valuing impacts primarily to recreation. In the area of habitat impacts and mitigation, he suggests that the Contingent Value Method (CVM) is the only way to convey a meaningful value to losses and gains. The difficult aspect of this is to educate those surveyed about the habitat in order for them to give meaningful responses. This can be done by relating the habitat to them through their interests, such as hunting, fishing, and other recreational activity.

PRIVATE INSTITUTIONS/INDIVIDUALS

Celeste Jarvis, Geo Decisions, Inc., (GDI):

Ms. Jarvis was instrumental in developing GDI/HEP, a computer software package which supports PAM HEP, the Pennsylvania modified version of HEP. PAM HEP has taken the strengths of HEP, the HSI models, and modified the data summary techniques. This has created a simpler, less time consuming, and less expensive technique while achieving similar conclusions. GDI/HEP has made PAM/HEP even simpler to use and provides an efficient approach for comparing and evaluating many alternatives for mitigation planning.

Raymond Kopp, Resources For The Future:

This organization is primarily involved with the valuation of damage on Superfund sites or an event such as a major oil spill. With the use of the "willingness to pay" method, values can be placed on lost opportunities such as recreation or bio-diversity. Whatever values are unable to be restored, are charged to those responsible for the loss. Mr. Kopp says that this procedure is the one authorized by the Department of the Interior in dealing with Superfund projects and feels it will establish guidelines for the future in the area of valuing natural resources.

Dennis MaGee:

Mr. MaGee was a co-developer of the "Holland-MaGee Method" of impact assessment and mitigation planning. The technique is similar to the WET approach but is quicker and more efficient. The method has the ability to look at several elements of a wetland and determine how alternations would impact them. The model will then indicate where appropriate mitigation measures are needed.

Barbara Rodes, Conservation Foundation:

This foundation is currently involved with a project involving cumulative impact statements. Although mitigation practices will be addressed in the study, the analysis will not be done in sufficient detail to add any insight to the IWR.

APPENDIX C

ECONOMIC BIBLIOGRAPHY

BIBLIOGRAPHY

Burn, Donald H., McBean, Edward A. (1985). Optimization Modeling of Water Quality in an Uncertain Environment. Canada

Clapham, W.B. (1983). Natural Ecosystems. MacMillan Publishing Co., New York. pp. 171-263.

This textbook provides the basic background needed to understand biological modeling. The complexity of natural ecosystems is described, including basic ecological linkages. Emphasis is placed on the flow and cycle of energy and materials that sustain life and looks at the populations and communities that constitute the living portion of ecosystems. The book concludes with an assessment of the implications of natural ecosystems in a modern society and how they may be affected.

Crocker, Thomas D. (1985). "On the Value of the Condition of a Forest Stock," JEL.

Studies on the value of forest recreation have focused on the entire experience package, thereby presuming that behavior is influenced largely by economic and demographic factors as opposed to variations in the landscape where the recreation occurs. Only with respect to harvested timber values have forest managers received appreciable guidance from economic analysis on managing the condition of the standing stock of vegetation. In this paper, a contingent valuation questionnaire is employed to gather economic data on air pollution damages to the vegetation stock of a national forest. Reductions in these damages are found to have increasing marginal benefits.

Dixon, J.A. and M.M. Hufschmidt. (1986). Economic Valuation Techniques for the Environment, A Cast Study Workbook. Johns Hopkins University Press. Baltimore. 148p.

The case studies evaluated in this workbook are based on the valuation techniques detailed in the text "Environment, Natural Systems, and Development: An Economic Valuation Guide." The workbook shows how some of the valuation techniques have been used in assessing development projects in the Asian-Pacific region.

Dorfman, R. and N.S. Dorfman. (1972). Economics of the Environment. W.W. Norton & Company, Inc. New York. pp.65-250.

In response to the widely felt concern that mankind has been depleting his natural resources and exploiting his environment, this collection of papers examine concepts and methods of economic analysis with a view of their application to environmental problems. A section is also provided which examines the pros and cons of the policies for environmental protection that emerge from the preceding analysis.

Duckstein, Lucien, Opricovic, Serafim. (1980). "Multiobjective Optimization in River Basin Development." Water Resources Research.

Eastman, John, ReVelle, Charles. (1973). "Linear Decision Rule in Reservoir Management and Design: 3. Direct Capacity Determination and Intraseasonal Constraints," Water Resources Research.

Farmer, A., P. Sorisa, R. Olsen, J. Hockenstrom, and G. Williams. (1986). A Microcomputer Program for Use in Designing Cost-Effective Habitat Management Plans. U.S. Fish and Wildlife Service, Weston Energy and Land Use Team, Fort Collins, CO.

This paper is a discussion of the current effort between the Bureau of Reclamation and the Fish and Wildlife Service to develop a habitat management model, named HMEM. This model incorporates the HEP system of habitat valuation with a cost-effectiveness approach to management measures. The paper includes an analysis of the model, some discussions and applications of its use along with the description of the model.

Gisser, Micha. (1970). "Linear Programming Models for Estimating the Agricultural Demand Function for Imported Water in the Pecos River Basin." Water Resources Research.

Hokenstrom, J. (1987). "Habitat Management Evaluation Model--A User's Perspective." Environmental Planning Conference, U.S. Army Corps of Engineers Seminar on Environmental Planning. pp. 311-320.

This paper reviews the Habitat Management Evaluation Model (HMEM) from a user's perspective, and its usefulness to mitigation planning. The article is based on the author's experience in using HMEM, and discusses what the model is capable of doing for a planner as well as its current limitations. An application of HMEM on a project in Central Dakota (CENDAK) was included to provide an example with the discussion.

Hockenstrom, J., G. Williams, P. Soresa, and B. Prome. (1986). On-Farm Mitigation-An Alternative Approach to Mitigating Fish and Wildlife Impacts of Irrigation Development. Unpublished manuscript. Office of Environmental Technical Services, U.S. Bureau of Reclamation and National Ecology Center, U.S. Fish and Wildlife Service.

In response to major difficulties with the HEP method of mitigation, BR and FWS performed a joint study to examine the concept of "on-farm" mitigation with individual landowners who would be receiving irrigation water from development of a project in South Dakota. This concept would place the costs for replacing habitat on each farmer instead of including these costs as part of the Federal project costs. Habitat unit values were assessed using techniques developed for the HEP, and habitat management or mitigation plans were developed using the Habitat Management Evaluation Model (HMEM).

Howe, C.W. (1971). Benefit Cost Analysis for Water System Planning. Publication Press, Inc. Baltimore. p. 141.

The objective of this book is to set forth some of the basic elements of a benefit-cost approach to water resources planning. An economic framework is provided for project design and selection based on the recognition that water projects have impacts extending beyond those capable of monetary quantification and that environmental, aesthetic, and equity impacts must be forecasted and described if projects are to be ranked in order of their contribution to human well-being.

Hufschmidt, M.M., D.E. James, A.D. Meister, B.T. Bower, and J.A. Dixon. (1983). Environment, Natural Systems, and Development: An Economic Valuation Guide. Baltimore: Johns Hopkins University Press.

This guide to economic valuation from the standpoint of the environment, natural systems, and development is an attempt to explicitly include environmental concerns into the project evaluation process. The approach recognizes that trade-offs exist between development and the goods and services provided by the environment, and the Guide offers a comprehensive approach to the problem of incorporating the environmental quality effects of development projects into the process of economic analysis and evaluation.

Knapp, Keith C. (1983). "Steady-State Solutions to Dynamic Optimization Models with Inequality Constraints." JEL.

Lipsey, R.G., P. Steiner, and D. Purvis. (1984). Economics. Harper & Row, Publishers. New York. pp. 425-453.

This book evaluates the complex interlocking system which influences our public policies and decisions and examines why it is necessary for government intervention to best suit people's hopes and needs. Emphasis is placed on understanding how the market system functions, including the coordination of thousands upon thousands of individual markets. Reasons why markets fail are also emphasized and a case is made for government intervention to address these failures and provide for the social good.

Liu, Pan-Tai. (1980). "Optimum Extraction of an Exhaustible Resource: A Mathematical Analysis." COLLECTIVE VOLUME. pp. 157-168.

Loomis, J.B. (1988). Benefits & Costs in Natural Resources Planning. A Western Regional Research Publication. W-133.

This document is an interim report of the progress made by regional research participants and cooperators toward improving the methodologies used in evaluating the economic efficiency of natural resource allocations. The objectives of this research are:

1. Conceptually integrate market and non-market based valuation

methods for application to land and water resource base services.

2. To develop theoretically correct methodology for considering resource quality in economic models and for assessing the marginal value of competing resource base products.

3. To apply market and non-market based valuation methods to specific resource base outputs.

Loomis, J.B., G. Peterson, and C. Sorg. (1984). "A Field Guide to Wildlife Economic Analyses." Trans. N. Amer. Wildl. and Natur. Resource. Conf. 49. pp. 315-324.

"The purpose of this paper is to identify and clarify several major sources of confusion that commonly inhibit effective wildlife valuation. First, economic values in the context of the Public Trust Doctrine are shown to be broader than the financial perspective often taken in practice. This is followed by clarification of concepts of economic efficiency. Common abuse of expenditure information is exposed, and the proper role of expenditures in analysis of economic impact is clarified. Finally, the important relationship between economic value on the one hand and resource quality and price on the other hand are explained." (p. 315.)

Loomis, J.B. (1987). Economic Analysis. pp. 785-804.

This paper describes concepts and measurement of economic values of wildlife in order to provide an overview of bio-economic analysis techniques, and to discuss some of the issues and common misconceptions about economic analysis of wildlife values.

Loomis, J.B. (-). "The Importance of Including Costs of Full Mitigation in Benefit-Cost Analysis and Guidance for Planning Actual Mitigation." Trans. N. Amer. Wildl. and Natur. Resource. Conf. 49. pp. 394-403.

"This paper serves two related purposes. The first is to show that the cost of full mitigation must be included in project benefit-cost ratios or such ratios are misleading. Second is to go beyond project evaluation to determine under what conditions complete mitigation is likely to be economically feasible to implement. In determining the actual economic feasibility of complete mitigation the nation of incremental analysis and the FWS's Mitigation Policy (1981) will be linked together. This provides FWS and construction agency biologists with a common framework for planning actual mitigation." (p. 394).

Matulich, S.C. and J.E. Hanson. (1986). "Modeling Supply Response in Bioeconomic Research: An Example From Wildlife Enhancement. Land Economics. Vol. 62 No. 3. pp. 292-305.

The framework presented in this paper offers a pragmatic and feasible approach to synthesizing cost functions essential to bioeconomic planning. An empirical model of

wildlife enhancement in a proposed Federal irrigation project illustrates this response framework. The paper discusses the fundamental differences between biologists and economists which tends to impeded progress to the development of efficient environmental policy.

Michan, E.J. (1971). Cost-Benefit Analysis: An Introduction. Praeger Publishers. New York. pp. 31-306.

This book provides an in-depth background to the use of benefit-cost analysis with emphasis on basic concepts and techniques. Case studies are provided which illustrate the fundamental principles of cost-benefit analysis and show how realistic decisions can be made which take into consideration the welfare of society as a whole.

Morris, J. (1987). "Evaluating the Wetland Resource." Journal of Environmental Management, Vol. 24.

This article provides an economic framework for examining the competition between agriculture and the environment. This framework is based on the Human Use and Economic Evaluation (HUEE) method which assigns value to environmental resources based on individuals willingness to pay. In addition, this article reviews other considerations in measuring costs, benefits, and impacts, and considers their contribution to resource decisions.

Moser, D.A. (1985). "Incremental Analysis in Mitigation." Unpublished paper. U.S. Army Corps of Engineers, Institute for Water Resources.

This article examines incremental analysis in mitigation. Examples are provided of applications of this approach to hypothetical environmental mitigation problems. Extensive documentation and technical support is provided in the development and application of this method.

Moser, D.A. (1987). "Overview of Bioeconomic Models." Unpublished paper. U.S. Army Corps of Engineers, Institute for Water Resources.

This document provides an extensive overview of available bioeconomic techniques. Specific models developed and evaluated include: Regression or Econometric approach; I-O analysis; Linear programming; Non-linear programming; and, Energy analysis. These techniques provide the conceptual basis for developing specific models to address the environmental impacts of COE projects.

National Wetlands Policy Forum. (1988). Mitigation Policy - Background Paper. Unpublished document. 15pp.

A basic introduction into the area of mitigation is presented in this paper by discussing it through three major sections: (1) the extent of mitigation or scope of the problem; (2)

current mitigation policies; and, (3) major mitigation policy issues. The paper suggests the two most effective tools available in the field of mitigation are the Habitat Evaluation Procedure (HEP), developed by FWS as an impact assessment tool, and the technique originally developed by FHWA as a planning tool, known as the Wetlands Evaluation Technique (WET).

Odum, H.T. and E.C. Odum. (1976). Energy Basis for Man and Nature. McGraw-Hill, New York.

This book examines energy principles and flows of energy in our environment. It includes patterns of systems, basic laws of energy, energy basis for humanity, and ways to use energy planning for the future. The Energy Analysis (EA) method which is based on changes in energy levels in biomass is developed in this book.

Palesh, G., R. Anfang, and R. Devendorf. (1987). "The Experience of the St. Paul District, Corps of Engineers, in Using Habitat Evaluation Procedures and Incremental Analysis for Mitigation Planning." Environmental Planning Conference Proceedings, U.S. Army Corps of Engineers Seminar on Environmental Planning, 15-18 March 1987 New Orleans, Louisiana. pp. 265-297.

"The St. Paul District, Corps of Engineers, has used HEP in the evaluation of fish and wildlife impacts and in the mitigation planning for nine projects since 1976. Incremental analysis of compensation features was conducted for three projects. Most of the District's experience with HEP has been in terrestrial and wetland systems rather than in aquatic systems. The District has found HEP to be a useful tool in impact analysis and mitigation planning provided the user recognizes the limitations of the methodology. The District's experience with incremental analysis is more limited and to date has been applied "after the fact" to comply with policy changes. Two on-going studies will more fully integrate incremental analysis into mitigation planning."

Shabman, L. (1979). "Mitigation Planning Under the Principles and Standards." Paper Presented at the Mitigation Symposium, Fort Collins, Colorado, July 19, 1977.

This article examines improvements to mitigation through stricter application of the Principles and Standards decision framework. Limitations of habitat evaluation techniques are examined, however, Shabman concludes that the development of tools such as HEP will improve mitigation analysis and increase mitigation associated with Federal projects.

Seneca, J.J. and M. Taussig. (1974). Environmental Economics. Prentice-Hall, Inc. Englewood Cliffs, New Jersey. 365p.

This book is aimed at blending economic theory with environmental facts and social circumstances. The theme of the book is the practicality of applying standard benefit-cost techniques such as incremental analysis in an Economic Framework based on the concept of efficiency to a wide variety of environmental problems. Basic economic principles are defined and evaluated which are necessary in understanding the mitigation problem.

Sniedovich, M. and D. Davis. (1975). Comment on "Chance-Constrained Dynamic Programing and Optimization of Water Resource Systems" by Arthur J. Askew. Water Resources Research, December 1975. p.1037-38.

Tietenberg, T. (1984). Environmental and Natural Resource Economics. Scott, Foresman and Company. London. p.38-83.

This book has a strong policy orientation and applies economic theories to many environmental problems. Insights from the natural and physical sciences, literature, and political science, as well as other disciplines are provided and linked in an economic framework which attempt to solve these problems. Contrasting points of view are also presented.

U.S. Army Corps of Engineers. (-). Draft Statement of Procedures for Incremental Mitigation Cost Planning when there are Land Acquisition (Fixed) Costs and Contributions to: a) One Mitigation Objective; or b) More than One Mitigation Objective.

This report addresses the problem of including land acquisition which represents a fixed cost into incremental cost planning. It is concluded that although the presence of a fixed cost somewhat complicates the task of incremental analysis, such an approach can still produce viable results.

U.S. Army Corps of Engineers. (1985). EP 1105-2-55: Fish and Wildlife Considerations, 25 February 1985.

This EP provides informational guidance on the consideration of fish and wildlife resource conservation during the planning of Federal water resources development including guidance on mitigation planning, incremental analysis, and the application of cost-sharing policy for such measures. It concludes that incremental analysis based on the non-monetary benefits and their associated costs in an economic sense, is not possible as the inputs and outputs are not the same, i.e., dollars. However, what is possible is a cost-effective or cost efficient analysis, which is getting the maximum benefit for the least cost.

U.S. Army Corps of Engineers. (1986). C6081106: Memorandum for the Director of Civil Works, Wildlife Mitigation. 7 August 1986.

This memorandum provided additional information to assist planners from the Mobile District in completing mitigation plans for the Tennessee-Tombigbee Waterway. Additional information included interpretations of wildlife mitigation measures and their effects on the marginal (or incremental) cost curve.

U.S. Army Corps of Engineers. (1986). National Economic Development Procedures Manual-Recreation: Volume II A Guide for Using the Contingent Value Methodology in Recreation Studies.

This report is designed to assist Corps planners in using the contingent value method (CVM) for the economic evaluation of NED recreation benefits. CVM along with the travel cost method (TCM) are the techniques recommended in Principles and Guidelines for evaluating the economic benefits from the recreational components of Federal water resources investments.

U.S. Army Corps of Engineers. (1987). Draft EC 1105-2-185, Fish and Wildlife Mitigation Planning: Incremental (Marginal) Cost Analysis, 11 March 1988.

This circular provides guidance on performing incremental cost analyses to support report recommendations for fish and wildlife mitigation measures involving compensation. This EC emphasizes the need to consider a variety of combinations of mitigation management measures and approximate the least cost means of achieving various levels of mitigation. An appropriate level of mitigation is not specified.

U.S. Army Corps of Engineers. (1987). EC 1165-2-XXX: Fish and Wildlife Mitigation and Enhancement; Benefits and Costs Attributable to Environmental Measures; and Mitigation Fund, 18 February 1987.

This draft circular provides guidance for mitigation planning including land acquisition, funding-level limitations, program administration, timing for implementation of mitigation and other related concerns and issues.

U.S. Army Corps of Engineers Institute for Water Resources Support Center. (1983). Analysis of U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service Transfer Funding Agreement.

The analysis was performed to determine the status of the relationship between COE district offices and FWS field offices in upholding the Transfer Funding Agreement (TFA). This agreement refers to the responsibility of the FWS to study environmental conditions in areas being studied for projects by the COE. The COE in return pays for this service. This analysis provides a background in the requirements set forth in the Fish and Wildlife Coordination Act (FWCA) which gives the authorization for the coordination between the two agencies.

U.S. Army Corps of Engineers Institute for Water Resources. (1984). WRSC-IWR Review of Proposed Revisions to ER 1105-2-50 and EP 1105-2055.

This discussion paper addresses the justification of mitigation and the use of incremental analysis in evaluating environmental resources. It concludes that incremental analysis is no an appropriate form of analysis for assessing the most efficient of effort level for mitigation because it is not compatible with the intent of compensation nor does it

provide an identifiable or consistent decision rate.

U.S. Army Corps of Engineers, Los Angeles District. (1985). Upper Santa Ana River Flood Storage Alternative Study, Appendix F.

This Appendix presents technical background information concerning existing resources and impact assessment associated with the recommended plan for flood storage. A HEP procedure was used to evaluate both direct and indirect losses including biological resources, cultural resources, and paleontological resources. These evaluations were used to determine mitigation needs and opportunities.

U.S. Army Corps of Engineers, Los Angeles District. (1988). Nogales Wash & Tributaries: Feasibility Report and Environmental Assessment.

This feasibility report is in response to flood problems on the flood plain of Nogales Wash/Potrero Creek located in southern Arizona. The recommended plan calls for channel improvements and enlargements which would disturb a fair amount of environmental resources. In response to this loss of valuable natural habitat, a mitigation study was completed using a HEP procedure in conjunction with an incremental analysis to determine the least costly plan for achieving 100 percent mitigation.

U.S. Army Corps of Engineers, Missouri River District. (1981). Fish and Wildlife Mitigation Plan, Missouri River Bank Stabilization and Navigation Project Final Feasibility Report and EIS.

This study develops a mitigation plan for the Missouri River Valley. The original navigation project was under construction at the time of passage of the Fish and Wildlife Coordination Act of 1958, which requires mitigation for all future projects as well as those current projects which were not yet 60 percent completed. The Missouri River Bank Stabilization and Navigation project fit into that category, yet mitigation measures were overlooked until this study in 1981. The study developed mitigation plan and selected one as the alternative best able to achieve the planning objectives as well as NED and EQ objectives. All mitigation plans developed for analysis were based on HEP, using Habitat Units in an incremental analysis framework.

U.S. Army Corps of Engineers, Mobile District. (1983). Wildlife Mitigation Feasibility Study, Volumes I, II, III: Tennessee-Tombigbee Waterway, Alabama and Mississippi.

The purpose of this study is to identify any unavoidable wildlife resource losses associated with construction and operation of the Tennessee-Tombigbee Waterway, and to formulate and select a mitigation plan. Several measurement techniques were used in conjunction with an incremental analysis including HEP.

U.S. Army Corps of Engineers, New Orleans District. (1986). West Bank of the Mississippi River in the Vicinity of New Orleans, LA: Feasibility Report and Environmental Impact Statement, Technical Appendixes.

This report provides a detailed example of how incremental analysis was used in conjunction with HES to determine the appropriate plan for mitigating losses associated with the enhancement of the Jean Lafittle National Historical Park. Five alternative mitigation plans were evaluated all achieving different levels of mitigation. The recommended plan represented an approach which would achieve 100 percent mitigation in the least costly manner.

U.S. Department of Agriculture. (1979). The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats General Technical Report RM-65, July 16-20, 1979.

This document contains the proceedings from a symposium on environmental mitigation held July 16-20, 1979 at the Colorado State University in Fort Collins, Colorado. Over 180 articles were presented in this book covering a wide variety of mitigation topics. Several articles provided examples of applications of HEP to environmental situations. Other articles explored topics such as linear programming in incremental analysis and many others.

U.S. Department of the Interior, Division of Ecological Services, Fish and Wildlife Service. (1980). Ecological Services Manual Habitat Evaluation Procedures, August 1980.

This manual describes the concepts behind and the rationale for a habitat evaluation methodology. Included in this analysis is the legal basis for environmental mitigation including detailed descriptions of the National Environmental Policy Act (NEPA), the Fish and Wildlife Coordination Acts (FWCA), and the Principles and Guidelines for Water Resources (P&G) which are fundamental in mitigation planning.

Vars, R.C. (1979). Wildlife Resources and Project Design Under New Federal Planning Initiatives. Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 19, 1977.

This paper presents an economic analysis of the proposed rules to implement the Fish and Wildlife Coordination Act, the Habitat Evaluation Procedures, and the Water Resources Council's proposed manual of procedures to evaluate project benefits and costs. The results show that these initiatives will make unacceptable some projects that would be acceptable under current evaluation procedures, reduce the habitat damages associated with some selected projects, but lend in some cases to the selection of a project plans with larger wildlife habitat damages than under current procedures.

Williams, G.L. (1987). An Assessment of HEP (Habitat Evaluation Procedures) Applications to Bureau of Reclamation Projects, 1980-85. Wildlife Society Bulletin, Winter 1988.

The evaluation of HEP is based on 15 BOR projects using these procedures for determining impacts to habitat. An assessment of the defining of mitigation objectives and the method of species selection was the basis of the evaluation. Compensation plans were discussed based on these evaluation factors. Conclusions from this study suggested the need for better methods for developing habitat management plans for compensation areas.

APPENDIX D

MITIGATION BIBLIOGRAPHY

BIBLIOGRAPHY

Adamus, P. and L. Stockwell (1983). A Method for Wetland Functional Assessment: Volume I. Center for Natural Areas for Offices of Research, Development, and Technology, Federal Highway Administration, U.S. Department of Transportation. FHWA-IP-82-24.

This manual is an in-depth look at the current efforts by the U.S. Department of Transportation to develop a method for an assessment of wetland valuation. This method, known as the WET-II model, evaluates wetlands based on criteria for their functional area and develops a methodology for evaluating impacts based on this criteria.

Adamus, P. and L. Stockwell (1983). A Method for Wetland Functional Assessment Volume II. Center for Natural Areas for Offices of Research, Development, and Technology, Federal highway Administration, U.S. Department of Transportation. FHWA-IP-82-24.

A continuation of Volume 1 of the same report as cited above.

Bane, G. W., A. W. Bane, S. Ellsworth. (1985). Literature Review of Wetland Fish and Wildlife Habitat Values in the United States, 1970-1983. U.S. Army Corps of Engineers Contract No.DACW39-83-M-1017.

Branch, K., J. Thompson, J. Creighton, and D. Harper. (1982). The Bureau of Land Management Social Effects Project: *guide to social Assessment. BLM-YA-PT-82-007-1606.

Clark, D. G. (1986). Benthic Resources Assessment Technique Evaluation of Disposal Sites in Puget Sound and Adjacent Waters. Environmental Laboratory, U.S. Army Corps of Engineers, Waterways Experiment Station.

This study evaluated the application of the benthic resources assessment technique (BRAT) to the assessment of disposal sites in the Puget Sound and adjacent waters. This data provided comparative assessments of benthic habitat quality at the study areas in terms of potential trophic support for bottom feeding fish. A recommendation was made based on the level of functional values for bottom feeding fish.

Desvousges, W. H. and V. A. Skahen. (1987). Techniques to Measure Damages to Natural Resources. U.S. Department of the Interior, PB88-100136.

This manual discusses valuation techniques used under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). Basic economic valuation concepts and the techniques or approaches economists use to measure damages are highlighted.

Erickson, P., G. Camorigis, and E. Robbins. (1978). Highways and Ecology: Impact Assessment and Mitigation. New England Research, Inc. for Federal Highway Administration, FHWA-RWE/OEP-78-2.

This book uses an ecosystem approach to impact assessments for federal highway projects disturbing terrestrial, aquatic, and wetlands ecosystems. The analysis is broken down into pre-design, design, construction, and operation and Maintenance phases. Case studies and references are given to provide access to a more in-depth analysis. It should be noted that although this publication provides basic guidance to field offices, some of the procedures may be out of date.

Farmer, S. (1985). "The Value of Coastal Wetlands for Protection of Property Against Hurricane Wind Damage." Journal of Environmental Economics and Management 14 (1987), p.143-151.

Federal Register. (1986). Interagency Cooperation - Endangered Species Act of 1973, as Amended; Final Rule. Department of the Interior, Fish and Wildlife Service, and Department of Commerce, National Oceanic and Atmospheric Administration.

Federal Highway Administration (FHWA), DOT. (1980). Mitigation of Environmental Impacts to Privately Owned Wetlands. 23 CFR Part 777. Federal Register, Vol.45, No. 149, July 31, 1980. p.50728-50731.

This document contains the Federal rules and regulations governing the FHWA approach to mitigation of wetland impacts. Policy and procedural methods for evaluation are discussed.

Gallagher, D.R. and V. K. Smith. (1984). Measuring Values for Environmental Resources Under Uncertainty. Journal of Environmental Economics and Management, Vol.12, No.2.

Garbisch, E. (1986). Highways and Wetlands: Compensating Wetland Losses. U.S. Department of Transportation, Federal Highway Administration Report No. FHWA-IP-86-22.

This report is a helpful guide to planners who desire an overview of the wetland creation process. It discusses aspects of a project including a site selection, procedures for establishment and a discussion of factors limiting success.

Hockenstrom, J., G. Williams, P. Soresa, and B. Prose. (1986). On-Farm Mitigation-An Alternative Approach to Mitigating Fish and Wildlife Impacts of Irrigation Development. Unpublished manuscript. Office of Environmental Technical Services, U.S. Bureau of Reclamation and National Ecology Center, U.S. Fish and Wildlife Service.

In response to major difficulties with the HEP method of mitigation, BR and FWS performed a joint study to examine the concept of "on-farm" mitigation with individual landowners who would be receiving irrigation water from development of a project in South Dakota. This concept would place the costs for replacing habitat on each farmer instead of including these costs as part of the Federal project costs. Habitat unit values

were assessed using techniques developed for the HEP; and habitat management or mitigation plans were developed using the Habitat Management Evaluation Model (HMEM).

Haug, P.T., R. W. Burwell, A. Stein, and B.L. Bandurski. (1982). "Determining the Significance of Environmental Issues Under the National Environmental Policy Act." Journal of Environmental Economics and Management, (1984) 18, 15-24.

Haug, P. T., R. W. Burwell, A. Stein, and B. L. Bandurski. (1982). "A Systematic Interdisciplinary Language for Environmental Analysis Under the National Environmental Policy Act." Journal of Environmental Management, (1984) 18, 1-13.

Johnck, Ellen. (1984). Mitigation Primer - What You Need to Know. Bay Planning Coalition.

This bocklet serves as an information source to permit applicants seeking a basic understanding of their mitigation responsibilities. A brief background on mitigation is provided which includes definitions and a summary of its historical growth through Federal legislation and State of California regulations, and current problems in mitigation. Also included is a brief discussion of the Habitat Evaluation Procedure and the mitigation land bank as tools in mitigation analysis.

Kahn, J.R., and W.M. Kemp. (1983). "Economic Losses Associated with the Degradation of an Ecosystem: The Case of Submerged Aquatic Vegetation in Chesapeake Bay." Journal of Environmental Economics and Management, 12, September 1985. Academic Press, Inc. pp.246-263.

Discussed in this article is a study which employs concepts from ecology and economics to study the diminution of submerged aquatic vegetation (SAV) in the Chesapeake Bay, and quantifies losses associated with this ecological alteration. A bioeconomic fisheries model is used to value the effects of reducing SAV populations to the fishing sector.

Kellert, S. R. (1979). Public Attitudes Toward Critical Wildlife and Natural Habitat Issues. U.S. Department of the Interior, Fish and Wildlife Service and Yale School of Forestry and Environmental Studies.

Kellert, S.R. (1980). Activities of the American Public Relating to Animals. U.S. Department of the Interior, Fish and Wildlife Service and Yale School of Forestry and Environmental Studies.

Kellert, S.R. and J.K. Berry. (1980). Knowledge, Affection and Basic Attitudes Toward Animals in American Society. U.S. Department of the Interior, Fish and Wildlife Service and Yale School of Forestry and Environmental Studies.

Kellert, S.R. and M.O. Westervelt. (1981). Trends in Animal Use and Perception in 20th Century America. U.S. Department of the Interior, Fish and Wildlife Service and Yale School of Forestry and Environmental Studies.

Kellert, S.R. and M.O. Westervelt. (-). Children's Attitudes, Knowledge and Behaviors Toward Animals. U.S. Department of the Interior, Fish and Wildlife Service and Yale School of Forestry and Environmental Studies.

Krieger, D.A., J.W. Terrell, and P.C. Nelson. (1983). Habitat Suitability Information: Yellow Perch. U.S. Fish and Wildlife Service. FWS/OBS-83/10.55. pp.37.

This publication identifies the methods used in determining Habitat Suitability Indices for this particular species. These models are defined to assist planners in determining mitigation needs using the HEP method of mitigation.

Kusler, J.A. (1987). "Wetland Restoration/Creation: A Science Perspective" (Draft Discussion Paper). National Wetlands Policy Forum.

Lunz, J.D., and D.R. Kendall. (1982). "Benthic Resources Assessment Technique, A Method for Quantifying the Effects of Benthic Community Changes on Fish Resources." OCEANS. September 1982. p. 1021-1027.

Discussed in this paper is a review of the benthic resources assessment technique (BRAT) and its applicability in measuring the effects of changes in the benthic community on fish resources. The quantified impacts expected from different dredged material disposal options can be compared and analyzed to ensure the best overall selection. These finding can also be useful in mitigation planning. The paper explains BRAT and verification procedures.

Morris, J. (1987). "Evaluating the Wetland Resource." Journal of Environmental Management, Vol.24, 1987.

This article provides an economic framework for examining the competition between agriculture and the environment. This framework is based on the Human Use and Economic Evaluation (HUEE) method which assigns value to environmental resources based on individuals willingness to pay. In addition, this article reviews other considerations in measuring costs, benefits, and impacts, and considers their contribution to resource decisions.

National Wetlands Policy Forum. (1988). "Mitigation Policy - Background Paper." Unpublished document. 15pp.

A basic introduction into the area of mitigation is presented in this paper by discussing it through three major sections: 1)the extent of mitigation or scope of the problem; 2)current mitigation policies; and, 3)major mitigation policy issues. The paper suggests the two most effective tools available in the field of mitigation are the Habitat Evaluation Procedure (HEP), developed by FWS as an impact assessment tool, and the technique originally developed by FHWA as a planning tool, known as the Wetlands Evaluation Technique (WET).

Palesh, G., R. Anfang, and R. Devendorf. (1987). "The Experiences of the St. Paul District, Corps of Engineers, in Using Habitat Evaluation Procedures and Incremental Analysis for Mitigation Planning." Environmental Planning Conference Proceedings, U.S. Army Corps of Engineers Seminar on Environmental Planning, 15-18 March 1987, New Orleans, Louisiana. p.265-297.

"The St. Paul District, Corps of Engineers, has used HEP in the evaluation of fish and wildlife impacts and in the mitigation planning for nine projects since 1976. Incremental analysis of compensation features was conducted for three projects. Most of the District's experience with HEP has been in terrestrial and wetland systems rather than in aquatic systems. The District has found HEP to be a useful tool in impact analysis and mitigation planning provided the user recognizes the limitations of the methodology. The District's experience with incremental analysis is more limited and to date has been applied "after-the-fact" to comply with policy changes. Two on-going studies will more fully integrate incremental analysis into the mitigation planning." (p.265).

Palmer, J. (1986). "Introduction to Pennsylvania Modified 1980 Habitat Evaluation Procedure," presented at an International symposium on Economic and Social Values of the Wildlife Resource. Syracuse, New York.

This report provides a basic overview of PAM HEP and evaluates its applicability to mitigation problems.

Pennsylvania Game Commission. (1986). Pennsylvania Modified 1980 Habitat Evaluation Procedure Instruction Manual.

The Pennsylvania Modified 1980 Habitat Evaluation Procedure (PAM HEP) is a habitat-based approach for assessing and mitigating fish and wildlife impacts of proposed water and land resource development projects. This book is a complete instruction manual of how to use PAM HEP covering such topics as its applicability, data collection requirements and selection of critical or unique habitats.

Rhoads, D.C. and J.D. Germano. (1986). "Interpreting Long-term Changes in Benthic Community Structure: A New Protocol." Hydrobiology 142: 291-308 (1986). Dordrecht, the Netherlands.

The emphasis of the paper is on the importance of documentation of long-term change in benthic ecosystems and assessing and managing the effects of these changes. Changes in secondary production, pollutant transfer within the food web, and the recycling of nutrients are included in the assessment techniques. Technical aspects of the documentation process, such as successional mapping are also discussed.

Shabman, L. (1979). "Mitigation Planning Under the Principles and Standards." Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 19, 1977.

This paper examines the assessment tools being developed to assist in mitigation planning. A section is provided which examines the limitations associated with the HEP procedure

and concludes that considerable judgement is left in the hands of those performing the analysis.

Sevin, A. (1987). "Guidance for Preparing and Processing Environmental and Section 4 (F) Documents." Office of Environmental Policy, Federal Highway Administration, U.S. Department of Transportation.

This FHWA technical advisory provides guidance to field offices on the handling of environmental impact statements. It recommends use of the methodology developed by the FHWA, "A Method for Wetland Functional Assessment Volumes I and II," (Adamus, P. 1983) for use in conducting this analysis. A thorough EIS will put decision-makers in a better position to determine the mitigation measures necessary to minimize harm to wetlands.

Slowinski, T.E., J.C. Staples, and R.C. Nelson. (1981). "Habitat Evaluation Procedures (HEP) 1980 Demonstration Program Evaluation Report: Little Calumet River, Indiana." U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service.

The Little Calumet River Flood Control Project was selected to be one of the early demonstration projects to test the newly developing HEP method of impact assessment and mitigation planning. The objective of the GDM was therefore not solely to address flood control alternatives but also to put HEP through an actual test to begin to determine its strengths and shortcomings. The report performs an in-depth analysis, evaluating the method based on acceptability, understandability, timeliness, and cost. It also offers a summary of the problems, frustrations, and usefulness of the HEP model as viewed by the planners.

Soltz, R. (1985). "Upper Santa Ana River Flood Storage Alternative Study, Chapter III: Biological Resources." U.S. Army Corps of Engineers, Los Angeles District. p.F-17, F-133.

The objectives of the biological resources study effort included the following: first, to determine the type and value of existing and future resources to be affected by the project; second, to determine the types and severity of project-related impacts to those resources; and third, to determine the mitigation needs and opportunities to compensate for project-related impacts.

After a detailed evaluation two types of mitigation were determined to be needed to compensate for project-related impacts. General mitigation measures are steps which can be taken which are not site-specific, but apply to a number of sites or to the area in general. Site-specific mitigation would also be needed. This would call for specific steps to be taken at a specific cultural site to minimize impacts.

Sousa, P.J. (1983). Habitat Suitability Index Models: Field Sparrow. U.S. Fish and Wildlife Service. FWS/OBS-82/10.62. 14pp.

This publication identifies the methods used in determining Habitat Suitability Indices for this particular species. These models are defined to assist planners in determining mitigation needs using the HEP method of mitigation.

U.S. Army Corps of Engineers. (1985). Fish and Wildlife Considerations. EP 1105-2-55.

U.S. Army Corps of Engineers. (1987). Fish and Wildlife Mitigation and Enhancement; Benefits and Costs Attributable to Environmental Measures; and Mitigation Fund.

U.S. Army Corps of Engineers. (1987). Fish and Wildlife Mitigation Planning: Incremental (Marginal) Cost Analysis.

U.S. Army Corps of Engineers. (1982). "Habitat Evaluation Procedures (HEP) Demonstration Program." (DRAFT).

This report performs an evaluation of the U.S. Fish and Wildlife Service Habitat Evaluation Procedure in four COE studies. The objectives of this research was to primarily assess the institutional adequacy of using HEP-80 to meet specific COE planning tasks during actual COE planning studies and to assess the technical adequacy of HEP as a habitat-based approach for characterizing fish and wildlife resources and for evaluating environmental impacts.

U. S. Army Corps of Engineers. (1980). "Investigation of the Relationship Between Land Use and Wildlife Abundance." Contract Report 80-C2.

This report is the first phase of a two-phase study on the relationship between wildlife resources and land use. This is the final report on the first phase of the study, and it includes a critical review of the state-of-the-art in relating habitat with terrestrial wildlife populations.

U.S. Army Corps of Engineers. (1988). "Memorandum: Fish and Wildlife Mitigation Planning: Incremental (Marginal) Cost Analysis."

U.S. Army Corps of Engineers. (1983). "Memorandum: Guidance for Fish and Wildlife Mitigation Planning."

U.S. Army Corps of Engineers. (1986). "Memorandum: Wildlife Mitigation."

U. S. Army Corps of Engineers. (1985). "Modification of the Francis E. Walter Dam and Reservoir."

In this study, PAM HEP is used in conjunction with an incremental analysis to determine the mitigation plan. This is the only example of PAM HEP being used in a federal water resources project.

U.S. Army Corps of Engineers, Chicago District. (1981). Public Notice: Little Calumet River, Indiana.

U.S. Army Corps of Engineers, Fort Worth District. (1980). "Walnut and Williamson Creeks - Expanded Flood Plain Information Study, Volume III."

The analysis performed in this study was intended as a planning tool to assist local decision-makers concerning future development of the region and its impact on wildlife. The Habitat Evaluation Procedure (HEP) is linked with the Corps' Spatial Analysis Methodology (SAM) which gives planners an idea of mitigation requirements for varying land use plans. This methodology considers relative value indices (RVI) when establishing habitat unit values. This method of valuation considers the relevance each of the selected species has to man, and ranks them accordingly.

U.S. Army Corps of Engineers, Huntington District. (1986). "Kanawha River Navigation Study: Interim Feasibility Report, Winfield Lock Replacement, Volume 4, Environmental Impact Statement." p.EIS-25 to 27, DOI letter (4/18/86) p.7; Vol. 4 p. D-1-4.

Included in the feasibility study and EIS is a discussion on the Energy Flow Model (EFM) for developing mitigation measures, and an implementation of the model to this proposed project. The findings from the EFM were that mitigation measures were not warranted, contradicting a similar study by FWS where mitigation measures were found to be necessary. Many views and opinions regarding these findings are also contained in the report.

U.S. Army Corps of Engineers, Institute for Water Resources, Water Resources Support Center. (1983). "Analysis of U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service Transfer Funding Agreement."

The analysis was performed to determine the status of the relationship between COE district offices and FWS field offices in upholding the Transfer Funding Agreement (TFA). This agreement refers to the responsibility of the FWS to study environmental conditions in areas being studied for projects by the COE. The COE in return pays for this service. This analysis also provides a background in the requirements set forth in the Fish and Wildlife Coordination Act (FWCA) which gives the authorization for the coordination between the two agencies.

U. S. Army Corps of Engineers, Los Angles District. (1988). "Feasibility Report and Environmental Assessment Nogales Wash and Tributaries, Nogales, Arizona."

This study includes a detailed description of the application of HEP in conjunction with an incremental analysis to select a plan to mitigate losses associated with channel improvements for Nogales Wash.

U.S. Army Corps of Engineers, Lower Mississippi Valley Division. (1980). "A Habitat Evaluation System for Water Resources Planning." Environmental Analysis Branch Planning Division.

This report presents the methodology for the Habitat Evaluation System (HES) used to evaluate the quality of different habitat types (e.g., lake, forest, stream) and comparing the relative environmental impacts which can be expected to result from alternative plans for water resources development. Included in this description is an evaluation of advantages and disadvantages associated with the HES method.

U.S. Army Corps of Engineers, Missouri River Division. (1981). "Fish and Wildlife Mitigation Plan, Missouri River Bank Stabilization and Navigation Project Final Feasibility Report and Final EIS."

The study develops a mitigation plan for the Missouri River Valley. The original navigation project was under construction at the time of passage of the Fish and Wildlife Coordination Act of 1958, which requires mitigation for all future projects as well as those current projects which were not yet 60 percent completed. The Missouri River Bank Stabilization and Navigation project fit into that category, yet mitigation measures were overlooked until this study in 1981. The study developed several mitigation plans and selected one as the alternative best able to achieve the planning objectives as well as NED and EQ objectives. All of the mitigation plans developed for analysis were based on four parts: habitat quality (acres), fish and wildlife population (lbs.), man-day opportunities, and habitat quality based on modified HEP.

U.S. Army Corps of Engineers, Mobile District. (1983). "Wildlife Mitigation Feasibility Study, Volumes I, II, III - Tennessee-Tombigbee Waterway, Alabama and Mississippi."

The purpose of this study is to identify any unavoidable wildlife resource losses associated with construction and operation of the Tennessee-Tombigbee Waterway, and to formulate and select a mitigation plan. Several approaches were used to develop mitigation plans, including a Habitat Evaluation Procedure (HEP) analysis, an Traditional Evaluation Procedure (TEP), and a Man-Day/Monetary Evaluation Procedure (MEP) analysis.

U. S. Army Corps of Engineers, New Orleans District. (1988). "Final Report and Final Environmental Impact Statement for Acquisition of Wildlife Mitigation Lands."

The purpose of this report is to present the results of post authorization evaluations by the Louisiana Department of Wildlife and Fisheries (LDWF), the U. S. Fish and Wildlife Service, and the COE which indicate that significant wildlife losses would result from construction of the project. A mitigation plan was recommended based on a comparison of HEP and HES.

U.S. Army Corps of Engineers, New York District. (1982). Habitat Evaluation of Existing Terrestrial Resources Central Passaic River Basin, NJ, May 1982.

This document is a planning aid report intended for use by the COE when using the HEP method to measure the quality and quantity of fish and wildlife habitats. The study area for this project was the Passaic River Basin in northeastern New Jersey and New York. Field data was collected and habitat evaluated for twelve species. This study provides the

basis for measuring both habitat losses and gains that may result from project implementation.

U.S. Army Corps of Engineers, Vicksburg District. (1982). "Re-evaluation Report, Main Report, and Environmental Impact Statement, Tensas River Basin Excluding Bayou Macon, Louisiana--01860."

U.S. Army Corps of Engineers, Vicksburg District. (1982). "Re-evaluation Report, Appendices 1-5 Tensas River Basin Excluding Bayou Mason, Louisiana--01860."

U.S. Army Corps of Engineers, Vicksburg District. (1982). "Re-evaluation Report, Appendices 6-11 Tensas River Basin Excluding Bayou Mason, Louisiana--01860."

U.S. Army Corps of Engineers, Waterways Experiment Station. (1986). "Environmental Impact Research Program." Series of 25 Technical Reports.

U.S. Department of Agriculture. (1979). "The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats General Technical Report." RM-65, July 16-20, 1979.

This document contains the proceedings from a symposium on environmental mitigation held July 16-20, 1979 at the Colorado State University in Fort Collins, Colorado. Over 180 articles were presented in this book covering a wide variety of mitigation topics. Several articles provided examples of applications of HEP to environmental situations. Other articles explored approaches such as linear programming and the Computerized Ecological Impact Evaluation Method. Many other topics were also covered.

U.S. Department of the Interior, Division of Ecological Services , Fish and Wildlife Service. (1980). Ecological Services Manual Habitat Evaluation Procedures, August 1980.

This report presents the methodology for the Habitat Evaluation Procedure (HEP) used to determine the value of fish and wildlife resources. The purpose of this effort is to describe the concepts behind and the rationale for a habitat-based methodology. Several other assessment methods are also evaluated. Included in this analysis is a discussion of advantages and disadvantages for each method.

U.S. Department of the Interior, Fish and Wildlife Service. (1981). "Habitat Evaluation Procedures, A Report on Fish and Wildlife Resources of the Dan River Basin, North Carolina and Virginia," August 1981.

This evaluation of the fish and wildlife resources of the Dan River Basin was conducted as a demonstration project to assess the validity of the 1980 version of HEP. It was concluded that the HEP generated data are reliable numerical expressions of resource quality and quantity. The overall credibility of the HEP version was questioned, however, because many of the models used were untested.

U.S. Department of Agriculture. (1985). "Riparian Ecosystems and Their Management: Reconciling Conflicting Uses." First North American Riparian Conference, Tucson, Arizona.

U.S. Department of the Interior, Bureau of Land Management, Idaho Falls District. (1987). "Pocatello Resource Management Plan and Environmental Impact Statement."

U.S. Department of the Interior, Bureau of Land Management, Los Cruces District. (1985). "White Sands Resource Area Draft Resource Management Plan and Environmental Impact Statement."

U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Army Corps of Engineers. (1982). "A Report on Habitat Evaluation Procedures Demonstration Project, Big Sandy Lake, Sabine River Basin, Texas."

In an effort to evaluate the developing Habitat Evaluation Procedures (HEP), the Fish and Wildlife Service and COE teamed up on this demonstration project. This evaluation was performed in conjunction with the planning procedure for a dam on the Sabine River Basin. The primary purpose of the HEP demonstration was to test the procedure's ability to provide resource planning information. Based on the study findings, an evaluation of the procedure was prepared. Suggestions and recommendations for a refined HEP model were also offered for consideration.

U.S. Department of the Interior, Fish and Wildlife, and U.S. Department of Commerce, Bureau of the Census. (1982). "1980 National Survey of Fishing, Hunting, and Wildlife - Associated Recreation." U.S. Government Printing Office.

U.S. Department of the Interior and U.S. Army Corps of Engineers. (1987). "Beaver Creek Draft Cumulative Environmental Impact Statement, Anchorage Alaska."

Williams, G.L. (1987). "An Assessment of HEP (Habitat Evaluation Procedures) Applications to Bureau of Reclamation Projects, 1980-85." Unpublished manuscript. 29pp.

Applications of HEP to several Bureau of Reclamation projects were reviewed and it was determined that in many instances, mitigation could have been accomplished at lower cost had more intensive management been attempted than what is normally considered in HEP studies.

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